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CORSE-81

The 1981 Conference on Remote Sensing Education

May 18-22, 1981

Purdue University
West Lafayette, Indiana

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Compiled by Shirley M. Davis, Purdue University

Preface

CORSE-81, Conference on Remote Sensing Education, was held May 18-22, 1981, at Purdue University. Co-sponsored by NASA and NOAA, the conference was organized and conducted by the Laboratory for Applications of Remote Sensing (LARS), an interdisciplinary laboratory within Purdue University.

The goal of the conference was to bring together remote sensing educators from across the country to exchange information and share experiences in establishing and improving remote sensing curricula in institutions of higher education. To meet this goal, the tone of the conference was informal, to encourage discussion and interaction among participants, and presentations focused on educational concerns, not research. In addition nine tutorial workshops were offered, serving a two-fold purpose: to give participants an opportunity to deepen their own knowledge of specific aspects of remote sensing and to enable participants to observe and experience the educational strategies adopted by other remote sensing educators.

Report Format

This report on the conference is meant to capture the essence of the conference. No attempt has been made to record all events in precise detail. Authored papers serve as summaries of the presentations and are included here as they were submitted by the speakers. In addition, notes compiled by session reporters mention the main discussion topics for all sessions, plenary as well as parallel. In case of parallel sessions, the names of persons attending the sessions are also given so that the reader interested in a particular session may know someone to contact for further information.

Because of the great popularity of the tutorial workshops, each is also represented by a brief outline of the major topics presented. The report concludes with an alphabetical list of participants, a list of exhibitors, and an index to papers by author.

Table of Contents

Acknowledgements

The conference co-chairmen wish to recognize the significant contribution to the conference made by the Planning Committee:

Dr. Nicholas Short, NASA - Eastern Regional Remote Sensing Applications Center
Dr. Thomas Lillesand, University of Minnesota
Dr. Edward Martinko, University of Kansas
Dr. Ron Marrs, University of Wyoming
Dr. Roger Hoffer, Purdue University
Dr. Marion Baumgardner, Purdue University
Dr. Harry Jones, NASA - Western Regional Applications Program
Dr. Buddy Atwell, NASA - National Space Technology Laboratories

Through the imagination and work of this committee, the session topics were formulated and many speakers and session chairmen were encouraged to participate. The breadth of contact of these committee members--across the country and across discipline lines--brought much of the richness in diversity we enjoyed at the conference. Very special recognition is due to Nick Short, the person who responded to the need for such a conference, sought the resources essential to a successful national conference, provided guidance throughout the planning stages, and took an active part in planning two plenary sessions and presenting two workshops.

Most grateful thanks, too, to Linda Couchon, Conference Coordinator from Purdue's Continuing Education Administration and the staff who assisted her; to the six session reporters, all students at Purdue: Jim Tilton, Tom Hennig, Doug Knowlton, Ellen Dean, Dan Krizan, & Sarah Nunke; and Dee Dee Dexter for secretarial support.

Finally, for providing the enabling funds, appreciation is given to NASA's Eastern Regional Remote Sensing Center at Goddard Space Flight Center and to NOAA's National Earth Satellite Service (NESS).

We are pleased indeed to have had the privilege of being a part of this very worthwhile conference.

John C. Lindenlaub
Shirley M. Davis

Conference Co-Chairmen

CORSE-81

The 1981 Conference on Remote Sensing Education

May 18 - 22, 1981

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Monday, May 18, 1981

Registration 8:00 am - 9:00 pm, Heavilon Hall, Room 010

9:30 - 11:30 am

Workshop 1a, Heavilon Hall, Room 128
Basic Principles of Satellite Remote Sensing
Nicholas Short, NASA/Goddard

1:30 - 5:00 pm

Workshop 2a, Heavilon Hall, Room 128
Digital Image Processing Techniques
Philip H. Swain, Purdue University and Ronald K. Boyd, Computer Sciences Corporation

Workshop 3, Heavilon Hall, Room 124
Energy Sources, Spectral Reflection Properties, Atmospheric Effects, and Sensors
Thomas Lillesand, University of Minnesota and Ralph Kiefer, University of Wisconsin

Workshop 4a, Heavilon Hall, Room 129
GIS Analysis: An Academic Approach and Experience
William Campbell, NASA/Goddard; Joseph Berry, Yale University; and Richard Hyde, Butler University

7:30 - 9:30 pm

Workshop 1b, Heavilon Hall, Room 128
Basic Principles of Satellite Remote Sensing
Nicholas Short, NASA/Goddard

Workshop 5, Heavilon Hall, Room 124
Acquisition and Use of 35mm Aerial Photography in Instruction and Research
Merle Meyer, University of Minnesota

Workshop 6a, Heavilon Hall, Room 120
Laboratory-Manual Approach to Remote Sensing Instruction
Floyd Sabins, University of California, Los Angeles

1. Tuesday Morning, May 19, 1981 - Fowler Hall, Stewart Center

Session Chairman: John C. Lindenlaub, Purdue University

8:30 Opening Comment

Welcome to Purdue
Dr. Robert Greenkorn, Vice President & Associate Provost & Vice President for Programs in PRF

8:50 - 10:05 Overview of Remote Sensing Education

Perspective on Remote Sensing Technology
Roger A. Holmes, General Motors Institute

A University Dean's Look at Remote Sensing
Grant Walton, Rutgers University

Report on the Status and Context of Remote Sensing Education in the U.S.
Richard Dahlberg, Northern Illinois University and
John Jensen, University of Georgia

Break

10:30 - 12:00 Panel Discussion: Skills, Needs, and Opportunities in Remote Sensing -- a Challenge to the Educational Community

Chairman of the Panel: Roger Hoffer, Purdue University

J. Robert Porter, Earth Satellite Corporation
Robert LeBlond, IDRC, Canada
James R. Davis, Phillips Petroleum Company
Gary Johnson, Technicolor Graphic Services, Inc.
Richard H. Gilbert, U.S. Department of Agriculture, Soil Conservation Service

2. Tuesday Afternoon, May 19, 1981 - Fowler Hall, Stewart Center

Session Chairman: Thomas Lillesand, University of Minnesota

1:00 - 2:15 Resources and Strategies for Teaching Remote Sensing

Survey of Instructional Material for Remote Sensing
Stanley A. Morain, University of New Mexico

Equipment and Approaches for Teaching Visual Image Interpretation
Joseph J. Ulliman, University of Idaho

Break

2:45 - 5:00 Panel Discussion: Requirements of Teaching an Interdisciplinary Technology; Considerations in Course Design from Various Discipline Perspectives

Chairman of the Panel: Thomas Lillesand, University of Minnesota

Agronomy
Marion Baumgardner, Purdue University

Civil Engineering and Water Resources
Ralph Kiefer, University of Wisconsin

Electrical Engineering and Interdisciplinary Programs
Philip Swain, Purdue University

Forestry and Range Management
Merle Meyer, University of Minnesota

Geography
John Estes, University of California, Santa Barbara

Geology
Floyd Sabins, University of California, Los Angeles

3. Tuesday Evening, May 19, 1981 - Heavilon Hall, Room 011

7:30 - 9:30 Poster Session
Session Chairman: Douglas Morrison, Purdue University

Multimedia in Remote Sensing Education
Fred J. Gunther, Computer Sciences Corporation

Remote Sensing - Present and Future
H. H.L. Bloemer, Ohio University

Digital Image Data Sets for Remote Sensing Instruction
J. Ronald Eyton, University of South Carolina

Some Considerations in Low-Cost Image Processing on a University Main Frame. The Penn State (ORSER) Experience
Brian J. Turner, Pennsylvania State University

Ground Photography for Improved Image Interpretation Training
Ray Lougeay, State University College, Geneseo, NY

Project Omega: An Introduction
Joseph M. Kirman, University of Alberta

Characteristics and Advantages of Using Return Beam Images from Landsat 3
Simon Baker, East Carolina University

Low-Cost Digital Image Processing at the University of Oklahoma
John Harrington, University of Oklahoma

Customized Short Courses in Remote Sensing
Shirley Davis and Luis Bartolucci, Purdue University

Remote Sensing of the Environment: Course Objective
Olin Mintzer and John Ray, Ohio State University

Landsat Technology Transfer to the Private & Public Sector through Community Colleges and Other Locally Available Institutions
Robert Rogers, Environmental Research Institute of Michigan;
Elaine Wallace, Wayne Community College
Robert Karowski, Michigan Planning and Development Commission
Eugene Jaworski, Eastern Michigan University

Performing and Updating an Inventory of Oregon's Expanding Irrigated Agricultural Lands
Madeline J. Hall, Oregon State University
(Presented by Anthony Lewis)

4. Wednesday Morning, May 20, 1981

8:30 - 11:30 Five concurrent discipline-oriented discussion workshop sessions that focus on resources and strategies for teaching remote sensing.

Session IV.a - Heavilon Hall, Room 111
Chairmen: Marion Baumgardner, Purdue University, and Merle Meyer, University of Minnesota

Topic: Agriculture, Forestry, and Range Management

Contributors:
David Lusch, Michigan State University

Session IV.b - Heavilon Hall, Room 124
Chairman: Ralph Kiefer, University of Wisconsin

Topic: Engineering and Water Resources

Contributors:
Warren Philipson and Ta Liang, Cornell University
Robert Ragan, University of Maryland, and J. Alan Royal, General Electric Company
Jack Hill, Louisiana State University
Harold Rib, U.S. Department of Transportation

Session IV.c - Heavilon Hall, Room 126
Chairman: John Estes, University of California, Santa Barbara

Topic: Geography

Contributors:
Arthur Hawley, University of North Carolina at Chapel Hill
Noel Ring, University of Lowell
Aulis Lind, University of Vermont
Paul Baumann, State University of New York at Oneonta
John Bounds, Sam Houston State University
Samuel Goward, Tina Cary, and Helene Wilson, Columbia University

Session IV.d - Heavilon Hall, Room 128
Chairman: Floyd Sabins, University of California at Los Angeles

Topic: Geology

Contributors:
R.W. Blair, Jr., Fort Lewis College
Kenneth Kolm, South Dakota School of Mines and Technology

Session IV.e - Heavilon Hall, Room 129
Chairman: Philip Swain, Purdue University

Topic: Interdisciplinary Programs

Contributors:
- Peter Murtha, University of British Columbia
- Wayne Myers, Pennsylvania State University
- Roy Chung, University of Northern Iowa
- Roy Welch, University of Georgia

5. Wednesday Afternoon and Evening, May 20, 1981 - Fowler Hall, Stewart Center

Session Chairman: Edward Martinko, University of Kansas

1:00 - 3:00

A Perspective on Low-Cost Digital Image Processing
Edward Martinko, University of Kansas

Low-Cost Digital Image Processing on a University Main-Frame Computer
Lee Williams, University of Kansas

Microprocessor-Based Image Analysis Systems
Harvey Wagner, Technicolor Graphic Services, Inc, EROS

Digital Image Processing on a Small Computer System
Ronald Danielson, University of Santa Clara

Considerations in Developing Geographic Information Systems Based on Low-Cost Digital Image Processing
Floyd Henderson and Michael Dobson, State University of New York at Albany

Break

3:30 - 5:00 Four parallel discussion session related to above topics will focus on practical considerations of these approaches.

Session V.a - Heavilon Hall, Room 111
Chairman: Lee Williams, University of Kansas

Topic: Experiences in the Implementation of Image Processing for Instruction on a University Main Frame

Contributors:
John R. Jensen, University of Georgia
J. Ronald Eyton, University of South Carolina
Brian J. Turner, Pennsylvania State University
Robert Rogers, ERIM

Session V.b - Heavilon Hall, Room 126
Chairman: Harvey Wagner, Technicolor Graphic Services, Inc.

Topic: Experience with Digital Image Processing on a Microprocessor System

Contributors:
Fred J. Gunther, Computer Sciences Corporation
Kenneth Green, Howard University
Dwight D. Egbert, Egbert Scientific Software

Session V.c - Heavilon Hall, Room 128
Chairman: Ronald Danielson, University of Santa Clara

Topic: Digital Image Processing on a Small Computer System

Contributors:
Neil Weber, Murray State University
Ron Danielson, University of Santa Clara

Session V.d - Heavilon Hall, Room 129
Chairmen: Floyd Henderson and Michael Dobson, State University of New York at Albany

Topic: Geographic Information System Considerations for Low-Cost Digital Image Processing

Contributors:
Francis Conant, Hunter College
Roger Miller, University of Minnesota
Nicholas Faust, Georgia Institute of Technology

OPEN HOUSE AT LARS

4:30 - 6:00 pm

Flex Lab 2, 1292 Cumberland Road

Buses to LARS will leave from the West door of Stewart Center between 4:30 and 5:15.

5:30 Social Hour and Banquet

The Trails
325 Burnett Road, Lafayette

A presentation on planetary remote sensing will be given by Dr. Thomas McCord, Hawaii Institute of Geophysics, University of Hawaii.

Buses to The Trails will leave LARS between 5:15 and 6:00; one bus will leave Stewart Center (West Door) at 5:45 and go directly to the Trails.

Bus transportation will be provided at the close of the banquet for the return trip to Campus.

6. Thursday Morning, May 21, 1981 - Fowler Hall, Stewart Center

Session Chairman: Nicholas Short, NASA/ERRSAC

8:30 - 10:05 NASA's Role in Remote Sensing Education

Remote Sensing Education in NASA's Technology Transfer Program
Richard Weinstein, Manager of Regional Remote Sensing Application Program, NASA Headquarters

Development of the University of Massachusetts Remote Sensing Program: A Grass-Roots Approach
Kevin Richardson, University of Massachusetts

The University of Kansas Applied Remote Sensing Program: an Operational Perspective
Edward Martinko, University of Kansas

Oregon Trails Re-Visited
Anthony Lewis, Oregon State University

Sources of Support for Remote Sensing Education
John Estes, University of California, Santa Barbara

Break

10:35 - 11:45 NOAA's Role in Remote Sensing Education

The Status and Outlook for NASA's Land Remote Sensing Program
Richard Weinstein, Manager of Regional Remote Sensing Application Program, NASA Headquarters

The Outlook for the NOAA Operational Landsat Program
Harold W. Yates, Director, Office of Research, NOAA

The Department of the Interior EROS Data Center Assessment
Russell Pohl, Chief of Data Production, EROS Data Center

The Survey of the Landsat Data User's Needs
Daniel Cotter, Acting Director of User Affairs Office

7. Thursday Afternoon, May 21, 1981 - Fowler Hall, Stewart Center

Session Chairman: Nicholas Short, NASA/ERRSAC

1:00 - 2:30 Panel Discussion: Remote Sensing--The Shape of the Future

Western Regional Applications Program
Donald Schwarz, San Jose State University

Eastern Regional Remote Sensing Applications Center
Richard Hill-Rowley, Michigan State University

Earth Resources Laboratory
Roy Welch, University of Georgia

Geosat Committee
Frederick B. Henderson, San Francisco

Break

3:00 - 5:00

Workshop 6b, Heavilon Hall, Room 120
Laboratory-Manual Approach to Remote Sensing Instruction
Floyd Sabins, University of California, Los Angeles

Workshop 7a, Heavilon Hall, Room 128
Non-Landsat Remote Sensing from Space
Nicholas Short, NASA/Goddard

Workshop 8a, Civil Engineering Building, Room 123
Introduction to Photogrammetry
Edward Mikhail, Purdue University

Thursday Evening, May 21, 1981

7:30 - 9:30 pm

Workshop 6c, Heavilon Hall, Room 120
Laboratory-Manual Approach to Remote Sensing Instruction
Floyd Sabins, University of California, Los Angeles

Workshop 7b, Heavilon Hall, Room 128
Non-Landsat Remote Sensing from Space
Nicholas Short, NASA/Goddard

Workshop 8b, Civil Engineering Bldg, Room 123
Introduction to Photogrammetry
Edward Mikhail, Purdue University

Friday, May 22, 1981

8:30 - 12:00 noon

Workshop 2b, Heavilon Hall, Room 128
Digital Image Processing Techniques
Philip Swain, Purdue University and Ronald Boyd, Computer Sciences Corporation

Workshop 4b, Heavilon Hall, Room 129
GIS Analysis: An Academic Approach and Experience
William Campbell, NASA/Goddard; Joseph Berry, Yale University; and Richard Hyde, Butler University

Workshop 9, Heavilon Hall, Room 124
Remote Sensing Field Research
Marvin Bauer, Purdue University

(This workshop includes a visit to the Purdue Agronomy Farm.)

Session 1-A

Overview of Remote Sensing Education

Highlights:

Conference Co-chairman John Lindenlaub called the conference to order.

Dr. Robert Greenkorn, Vice President and Associate Provost of Purdue University, welcomed the participants to Purdue and spoke briefly on how interdisciplinary operations such as the Laboratory for Applications of Remote Sensing are carried out at Purdue.

Presentations were made by R.A. Holmes, G. Walton and R. Dahlberg. Copies of the papers which formed the basis of their remarks appear on the following pages.

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May 18-22, 1981 Session No. 1

Perspective On Remote Sensing Technology

Roger A. Holmes
General Motors Institute

As an observer and participant in remote sensing technology for sixteen years, with an admitted bias towards agriculture, renewable resources, and machine processing, I find it useful to consider a complete remote sensing system as four components with some overlap, and trace the developments in these components in four distinctive eras.

The four components are shown in Figure 1. Scene understanding includes knowledge of cause/effect relationships between scene attributes (leaf area index, planting date, soil moisture, atmospheric properties, etc.) and radiation flux arriving at the aperture of an active or passive remote sensor. Data acquisition includes sensor operation and calibration, and on-board and ground signal processing necessary to present valid radiametric and geometric data for information extraction. Information extraction includes recognition of spatial, spectral, and temporal patterns in the data which leads to valid inferences about the scene attributes. Information utilization includes extracted information reporting and its influence upon economic, political, or social decision processes.

The pre-space era spans from aerial photography to the 1969 Apollo 9 suborbital flight when multispectral camera data became available. Prior to then, with the exception of a few photographs from the Gemini program, little or no data from space were available to the general community. Figure 2 shows my views of the major outcomes of that pre-space era. Photographic aircraft data were common; multispectral scanner data were rare, with the primary data acquisition system a pair of locally modified ax-blade scanners flown by what is today the Environmental Research Institute of Michigan. Scene understanding was limited to gross statements like "It rained three weeks in May so we really have two distinct stands of corn out there, planted before or after the rain", and some crude spectral measurements. Information extraction by eyeball from photos was common. Machine signal and information extraction processing was rare and done primarily at LARS, Purdue, and Michigan with tapes from Michigan aircraft scanner flights. Information utilization efforts focused on getting any potential user through the door to at least look at the promise of the technology. Yet this era was characterized by very rapid learning of tenets of the technology that are still being absorbed by the full remote sensing community. Major lessons learned:

- Machine data processing people need photographic data and will use it extensively.
- Spatial, spectral, and temporal data are all required in renewable resources information extraction.
- Gross aspects of scene understanding (it rained three weeks in May) will often be far more important to successful information extraction than the choice between pattern recognition algorithms or the choice of this or that set of wavelength brands; hence, get all the ancillary data possible.
- There are no sharply distinctive spectral signatures; each scene must be analyzed with respect to its own data structure.
- Phooey on on-board processing; someone will always want to process the raw data for some purpose not even imagined at the time of the data flight.
- Field measurements for scene understanding require careful planning for completeness, adequate calibration, and comparability from data set to data set, and should form the basis for future sensor designs.
- Intermediate and far infrared wavelength data are valuable.
- The photographic technology is mature; the machine processing hardware and operating system technology is in a state of massive, rapid change, tending toward better systems at lower cost.
- Sun angle, view angle, and atmospheric constituent effects are important.

The second era, which I'll call the space threshold era, spans a brief but productive three years from Apollo 9 to the eve of the launch of ERTS A (the now-silent LANDSAT 1) in 1972. Figure 3 shows my view of the essence of this era. The infestation of the Southern corn blight into the Midwest brought about a timely test of the quasi-operational machine information extraction capabilities in the Corn Blight Watch Experiment. Analysis techniques using spectral pattern recognition were applied to the Apollo 9 multispectral camera photos after digitization of Earth scenes, with considerable success. The era was also characterized by an intensive flurry of proposal writing for the Skylab Earth Resources Experiments Program and ERTS-A investigations; expectations ran high. My general impression as a reviewer: many small, individual, or small team efforts; very few major attempts to use the full capability of the ERTS-A system; few real users involved, mostly federal government scientists and university professors specializing in remote sensing technology. Major lessons learned:

- Expansion of machine information extraction techniques to major data loads is not simple.

- Real user community will not be easily developed.
- Technology developments will continue in the direction of automated information extraction.
- Ground truth and scene understanding are essential to successful information extraction; not easy to do over large scenes.
- The importance of scene-specific crop calendars is recognized.

The third era, which I'll call the LANDSAT era, spans the time from the ERTS-A (later LANDSAT) launch to 1978, the transition from LACIE to AgRISTARS. The Skylab/EREP experience came and went; no lasting effects, in my view due to the fractionated program plus a once-only aura. On the other hand, the global wheat survey entitled the Large Area Crop Inventory Experiment (LACIE), based on LANDSATS, was a pioneering effort in this era. It was the first attempt at a multi-agency, quasi-operational mission of major magnitude on a crop of global significance with real-time performance demands and a clear criterion of success or failure. My views of this era are shown in Figure 4. There were several valuable lessons in the LACIE. They were and are:

- The human plays an intimate, in-line, on-line role in the information extraction system. The human is not a supervisor or onlooker, but a part of the system.
- The human-machine interaction area is an extremely fruitful area for technology advancement and may be the critical technology to achieve cost-effective operational systems.
- It is still true that fine-tuning of pattern recognition algorithms is relatively sterile.
- The concept of signature extension (train classifiers on one site, use same classification on nearby sites) failed; some hope of achieving such efficiencies requires the development of partitioned sampling on agrophysical features.
- Temporal information at least twice in the growing season is essential to crop recognition; problems even so as in spring wheat and barley separation.
- Yield research to develop production estimates is in its infancy, same with crop calendar modeling. Both are essential.
- Meteorological and agricultural ancillary data are vital.
- Spatial edge effects are important for small fields and LANDSAT 90 m pixel size.
- Procedures must be established to insure independent random samples for unbiased pattern recognition feature labeling.
- Users of information were, at last, making inputs to the design of operational systems.
- Scene understanding advances were made through coordinated field measurements programs on several LACIE 5 x 6 nm segments, and intensive concerns for scene and atmospheric modeling.

The AgRISTARS-and-beyond era began in the late 1970's. My perspective as we head for the middle 80's are:

On scene understanding -- Much progress was made in the LANDSAT era in developing cause and effect relationships between scene attributes and radiametric measurements, including atmospheric effects. Canopy modeling in two and three dimensions is developing, as is atmosphere-canopy coupling. Yield and crop calendar modeling on a biophysical cause/effect basis has begun recently.

Visible and IR modeling appears to be more advanced than microwave modeling.

On data acquisition -- With line-start and tape recorder problems on LANDSATS currently in orbit, and delays in LANDSAT D, there is the spectre of loss of the primary space data source. Ground data processing difficulties from system changeover at GSFC have delayed data tape and imagery deliveries. Space thermal emissive IR data at LANDSAT resolutions have not been seen and good space radar data exists but in tantalizing small amounts. Thematic Mapper is late, and handling data transmission rates of 100 Mb/s expected therefrom will require a learning period, hence probable lack of widespread availability. Registration and rectification of data remains unfinished business, hardly operational. In short, the weakest link in the remote sensing system today may be the very portion most strong in the 70's -- the engineering hardware and signal processing hardware/software. Current desires to develop image plane scanners with detector arrays and phase out object plane scanners may exacerbate matters. It is not clear when NOAA will fully absorb the charter for an operational system.

On information extraction -- We came off the LACIE experience rich in insights on the human-machine-image interface arena. Good work is underway in AgRISTARS to incorporate these insights into a maximum information/dollar low labor cost system, essential to operational system acceptance. The solution appears to be a system which efficiently presents to the human all pertinent data for necessary human decisions, trains the human to function in an expert analyst manner and uses the machine for chores best suited to it. Rapid technology advances in computing machines and image processing will make for exciting advances in information extraction abilities through the 80's and 90's.

On information utilization -- In the Domestic Crops and Land Cover portion of AgRISTARS data will be gathered over 10 states in the USA by 1985 to enhance operational agricultural statistical crop reporting. Foreign commodity production forecasting is headed for similar near-operational character though at a slower pace. Non-renewable resource users appear to have a well-developed record of remote sensing application. In my view the greatest deterrent to more rapid development in information utilization stems from delays in the data acquisition system.

All in all, we may have now arrived at the beginning of a whole second generation of remote sensing developments in which new (and needed) data acquisition gear will call for even better scene understanding in order to extract more timely information efficiently for those information users who got hooked on the first round. And this may uncover even more of those elusive phantoms of the remote sensing opera - the REAL user. The interactions shown in Figure 5 go on and on.

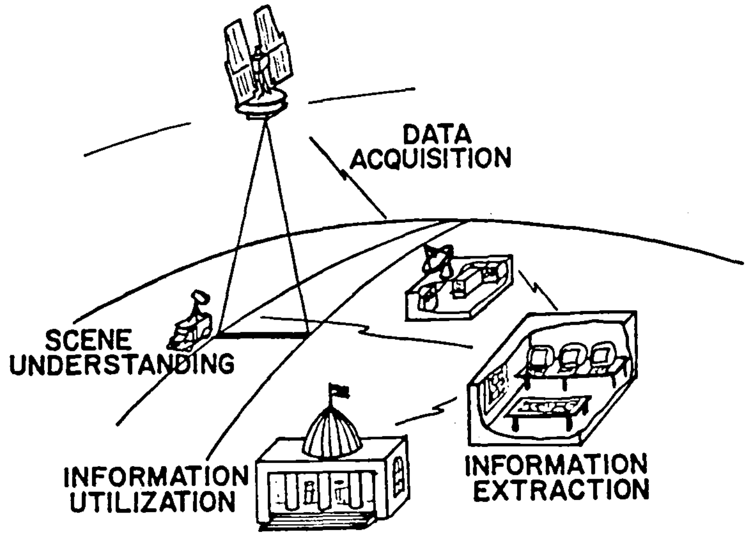

Figure 1.

PRE-SPACE ERA (PRE-1969)

PHOTOINTERPRETATION MATURES
USER FAVORITE

MS SCANNER VALUE PROVEN
ERTS A MSS & RBV ON THE WAY

MACHINE PROCESSING LEAVES INFANCY
PROMISES, PROMISES

Figure 2.

SPACE THRESHOLD ERA (1969-1972)

PHOTO DATA PRIME THRUST
EREP + EROS DELIVERY SYSTEMS

CORN BLIGHT TECHNOLOGY TEST
REAL TIME, LARGE AREA

MACHINE PROCESSING LEAVES CHILDHOOD
MSS CCT'S GRIST FOR THE MILL

Figure 3.

LANDSAT ERA (1972-1978)

GLOBAL PHOTO MAP EFFORT
SEE YOUR PEA PATCH FROM SPACE

MSS OK, SKYLAB PHOTOS OK
ENOUGH BANDS, RESOLUTION FOR NOW

LACIE NEAR OP GLOBAL SURVEY
REAL TIME, HARD CRITERIA
HUMAN-MACHINE EXPERIENCE

Figure 4.

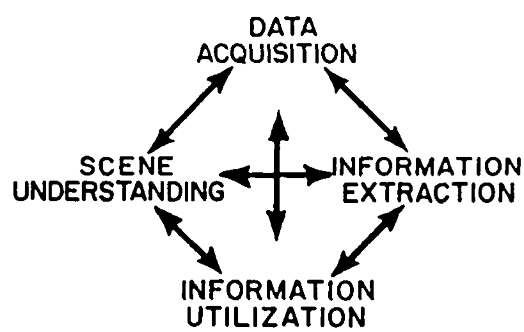

Figure 5.

NASA

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AN ACADEMIC ADMINISTRATOR'S CONSIDERATION OF REMOTE SENSING, OR THE EDUCATION OF A DEAN

Grant F. Walton, Dean of Cook College, Rutgers the State University
Director of New Jersey Agricultural Experiment Station

It is irrefutably evident that we are in an era of short money supply, decreasing enrollments, both graduate and undergraduate, and spiralling costs. Coupled with these is the demand by students for more relevant courses and programs--ones that will help them reach their career objectives (or to get a job). There is, however, a counter-trend for more professional improvement, in-service training for employees who need retooling to catch up to stay abreast with the new technologies and advances in existing technologies.

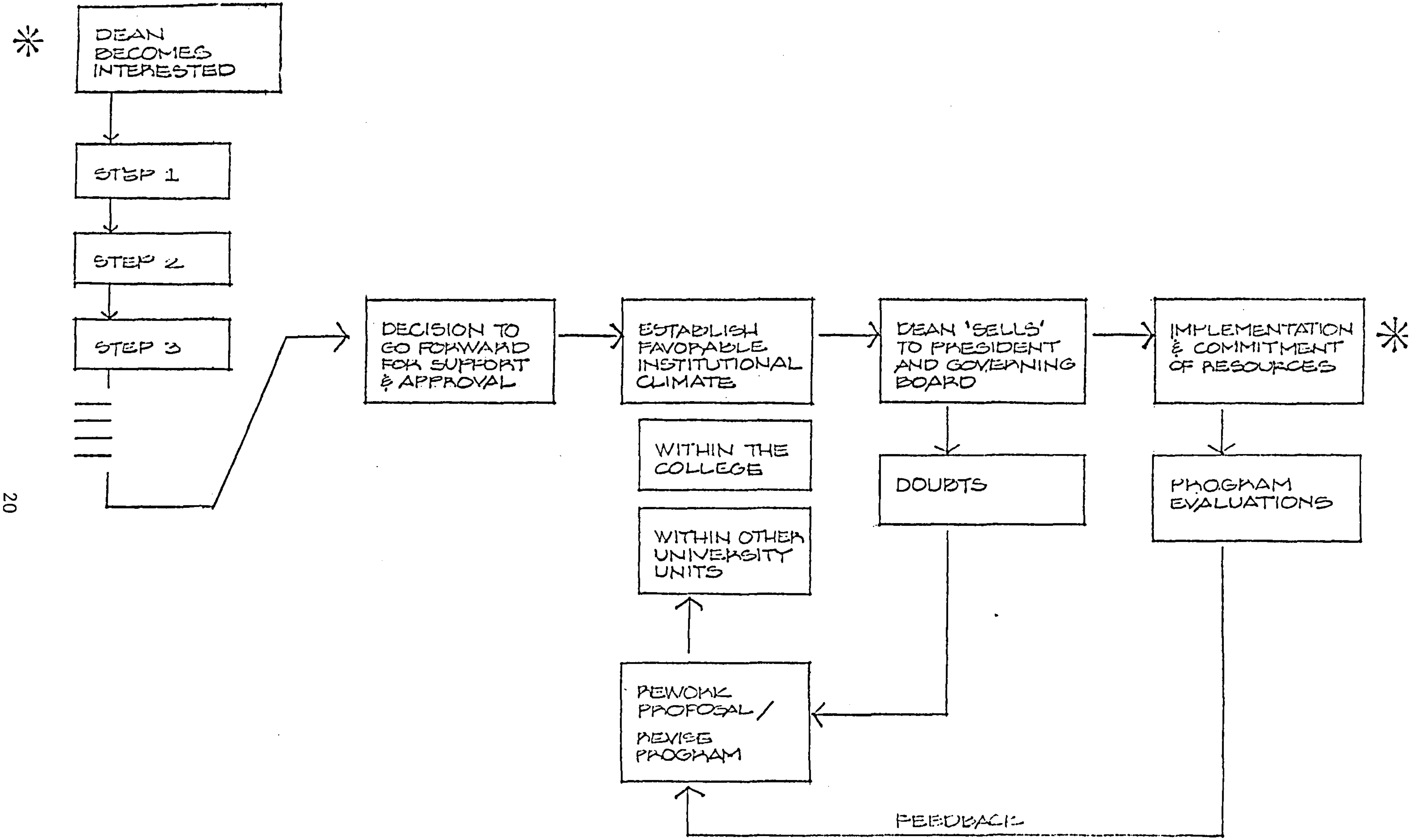
Similarly, there is a great need and interest in assisting the lesser developed countries (LCD's) to make use of many of the resource development technologies currently available. These and other conflicting factors are contributing to the increased competitiveness and tension within colleges and universities. Departments of Higher Education, as well as individual universities themselves, have vigorously engaged in the pursuit of greater accountability and review and re-review of existing programs. Some of these activities have resulted in large layoffs of university personnel because of the shortages of funds and the concerns that the programs which these individuals respresent are no longer needed or demanded.

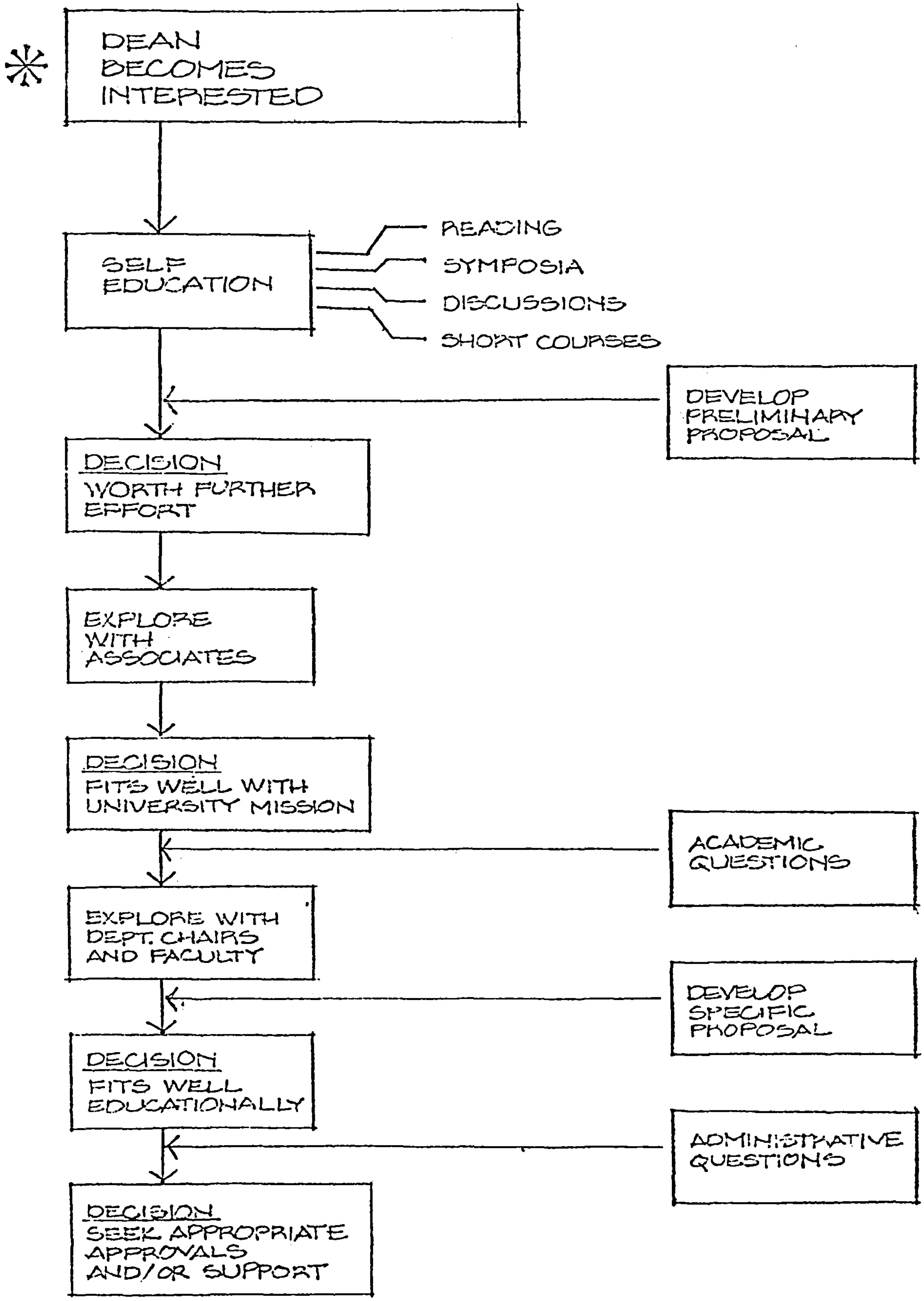
The university or college dean becomes engaged in many of these introspective analyses in their institutions. I thought it might be useful, then, to you as a group of educators interested in building new programs or expanding existing ones, to share with you the way in which at least one dean involved himself in the development of a remote sensing program. What I try to show in this presentation is the system I used to determine whether or not remote sensing should be encouraged to develop within our university. The model I present to you today is, I believe, a fair representation of the process I used to arrive at the decision. I would hasten to point out that this is not the ideal model, nor is it the only model to be followed, but, in sharing it with you my major intent is to help you understand the way a dean must look at any program proposal. A dean's perspective, by the very nature of his or her responsibility in a university, will probably be quite different from that of the classroom teacher or laboratory researcher. Perhaps by spending a few minutes looking over the dean's shoulder as he looks at the program will aid you in your "selling" of that program to your administration. I certainly hope that this presentation will be useful.

The premise is no matter how good an idea it needs the understanding and support of a person in a key administrative position in order for the program to advance in the highly competitive and charged atmosphere we refer to as "the university community". The first flow chart provides the overall perspective of the system. The next chart indicates the steps followed to arrive at the initial determination: it was worthwhile to proceed with the proposals to the upper level decision-makers within the university. You will note, I indicate several principal responsibilities and activities a dean must become involved with in advancing the program. First, of course, is to become personally interested and knowledgeable to some degree. The second is to provide a favorable climate within the unit to be principally responsible for the activity. At the same time, however, it is imperative not to lose sight of the fact that there are other units in the university that should be brought into the decision-making process and may, also, be in a position to contribute to and be beneficiaries of the program. The third involvement is in the actual selling of the program to the decision-making board of the institution as well as the president. Of course, I would put the president first and try to involve his office in selling the program up to the governing board. And the fourth involvement is a continuing one: to see that both implementation and evaluation of the program are carried out with the appropriate feedbacks.

There are several sets of questions that must be addressed in the process. First are those of an academic nature to determine whether the remote sensing fits in comfortably as an educational activity. The second set of questions are those I have termed to be administrative; these are ones in which the faculty would not be directly involved. The third set of questions are basically ones of a personal nature, that is, those the administrator must ask of himself. The questions are: (1) Am I willing to redirect lines (positions) into the program? (2) Am I willing to invest my time and energy to assist to get the program started, staffed and adequately funded? (3) Am I willing to identify and give up "weak" programs in order to support this one?

If the administrator can answer these questions positively, then we can agree that the program has a very good chance of getting support further up the administrative ladder and can become a successful undertaking. In my own case, I was able to answer "yes" to these questions and, consequently, we are moving the program forward.


DEAN BECOMES INTERESTED
STEP 1
STEP 2
STEP 3
DECISION TO GO FORWARD FOR SUPPORT & APPROVAL
ESTABLISH FAVORABLE INSTITUTIONAL CLIMATE
WITHIN THE COLLEGE
WITHIN OTHER UNIVERSITY UNITS
DEAN 'SELLS' TO PRESIDENT AND GOVERNING BOARD
DOUBTS
IMPLEMENTATION & COMMITMENT OF RESOURCES
PROGRAM EVALUATIONS
REWORK PROPOSAL / REVISE PROGRAM
FEEDBACK


DEAN BECOMES INTERESTED
SELF EDUCATION
READING
SYMPOSIA
DISCUSSIONS
SHORT COURSES
DEVELOP PRELIMINARY PROPOSAL
DECISION
WORTH FURTHER EFFORT
EXPLORE WITH ASSOCIATES
DECISION
FITS WELL WITH UNIVERSITY MISSION
ACADEMIC QUESTIONS
EXPLORE WITH DEPT. CHAIRS AND FACULTY
DEVELOP SPECIFIC PROPOSAL
DECISION
FITS WELL EDUCATIONALLY
ADMINISTRATIVE QUESTIONS
DECISION
SEEK APPROPRIATE APPROVALS AND/OR SUPPORT

EXPLORING POTENTIAL WITH DEPARTMENT CHAIRS & FACULTY

- TEACHING
  - WHAT IS THE PLACE OF REMOTE SENSING IN THE UNIVERSITY CURRICULUM?
  - IN WHAT SCHOOLS SHOULD SUCH COURSES BE TAUGHT?
  - AT WHAT LEVELS SHOULD THEY BE AIMED?
  - WHAT STUDENTS SHOULD BE INTERESTED IN THESE COURSES?
  - HOW CAN COURSES WHICH CUT ACROSS SO MANY DISCIPLINES BE EFFECTIVE?
  - WHAT DOES THE FUTURE HOLD FOR REMOTE SENSING EDUCATION IN A UNIVERSITY CURRICULUM?
- RESEARCH
  - WHAT ELEMENTS OF REMOTE SENSING LEND THEMSELVES TO BASIC RESEARCH?
  - WHAT ELEMENTS OF REMOTE SENSING LEND THEMSELVES TO R & D?
  - WHAT DEPARTMENTS/INDIVIDUALS MIGHT ON THEIR OWN VOLITION HAVE AN INTEREST IN REMOTE SENSING RESEARCH?
  - WHAT ONES MIGHT BE PERSUADED?
  - WHAT RESEARCH LINKAGES MIGHT BE FOSTERED BETWEEN OUR DEPARTMENTS AND GOVERNMENT AGENCIES?
  - WHAT COOPERATIVE RESEARCH ACTIVITIES MIGHT BE UNDERTAKEN WITH OTHER UNIVERSITIES?
- EXTENSION
  - WHAT IS THE POTENTIAL FOR ESTABLISHMENT OF TECHNOLOGY TRANSFER TEACHING PROGRAMS?
  - WHAT IS THE POTENTIAL FOR ASSISTING STATE GOVERNMENT AGENCIES ON SPECIFIC PROBLEM USING REMOTE SENSING TECHNOLOGY?
  - WHAT IS THE POTENTIAL FOR ASSISTING INDUSTRY IN SIMILAR FASHION?

ADMINISTRATIVE TYPE QUESTIONS & ISSUES

- DOES IT MEET AN IDENTIFIED EDUCATIONAL NEED?
- WHERE ARE THE LEADING PROGRAMS IN THE COUNTRY?
- WHAT ARE THE SCOPE AND FOCUSES OF THEIR PROGRAMS?
- HOW SUCCESSFUL ARE THEY AT PLACING THEIR GRADUATES?
- WHAT ARE THEIR COSTS? START-UP; SHORT-TERM; LONG-RUN?
- WHAT ARE THEIR SOURCES OF FUNDING?
- WHAT ARE THEY PROJECTING AS THE FUTURE OF THIS FIELD?
  IN 5 YEARS? 10 YEARS? 20 YEARS?
- IS OUR PROPOSED PROGRAM COMPETITIVE, CONFLICTING OR
  COMPLEMENTARY WITH ALL OR SOME OF THE LEAD PROGRAMS?

- WITHIN UNIVERSITY WHERE IS THE LEADERSHIP FOR THIS ACTIVITY?
- HOW GOOD IS IT? HOW RELIABLE? HOW DYNAMIC?
- WHAT RESOURCES ARE CURRENTLY AVAILABLE WITHIN THE UNIVERSITY
  WHICH COULD BE RECHANNELED TO SUPPORT PROPOSAL?
- WHAT ARE THE OUTSIDE FUNDING POSSIBILITIES?
  ARE THEY FOR START-UP, SHORT-TERM, LONG-TERM?
  DO THEY REQUIRE AN INSTITUTIONAL MATCH--IN KIND OR SOFT?
  HOW SECURE ARE THEY?

- DO WE HAVE THE INTEREST, RESOURCES AND LEADERSHIP TO DEVELOP
  AN OUTSTANDING PROGRAM?
- AM I WILLING TO REDIRECT LINES (POSITIONS) INTO THE PROGRAM?
- AM I WILLING TO INVEST MY TIME AND ENERGY TO ASSIST TO GET
  THE PROGRAM STARTED, STAFFED AND ADEQUATELY FUNDED?
- AM I WILLING TO IDENTIFY AND GIVE UP "WEAK" PROGRAMS IN
  ORDER TO SUPPORT THIS ONE?

CORSE-81

The 1981 Conference On Remote Sensing Education
May 18-22, 1981 Session No. I

STATUS AND CONTEXT OF REMOTE SENSING EDUCATION IN THE UNITED STATES

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1. INTRODUCTION

This review will focus upon selected aspects of the system of remote sensing education in the United States. It is difficult to profile this system in brief terms. This system is complex and in a state of flux and basic data about the system are just now being developed. Despite impressive recent growth, the system continues to be characterized by its predominantly horizontal structure. Opportunities for students to specialize in remote sensing are not yet numerous. One of the special difficulties in delineating the system arises from the fragmentation of remote sensing courses among a diversity of established disciplines. The emergence of remote sensing as a multi-disciplinary applied field presents many challenges to educators.

2. REMOTE SENSING EDUCATION TODAY

The product of recent rapid growth, remote sensing education presently is configured more in a service role to resource- and planning-oriented disciplines than it is to provide training for students wishing to specialize in the field. This strong client-orientation is manifested in the broad pattern of introductory course offerings.

2.1 INSTITUTIONAL CONTEXT OF REMOTE SENSING

The majority of remote sensing education is to be found in public supported institutions having strong graduate program orientations. Approximately 88 per cent of remote sensing courses are offered by public institutions and over 90 per cent of the courses are offered by institutions having graduate level programs (Table 1). It is evident from the data that much the same pattern obtains for the mapping sciences generally with the exception of surveying which is strongly concentrated in two-year colleges.

The diversity of academic homes of remote sensing is evident from the summary data in Table 2. In terms of numbers of courses offered, the social sciences rank first with 37 per cent of all courses followed by the physical sciences with 25 per cent, engineering with 19 per cent and agriculture and natural resources with 10 per cent. Also evident from these data is the virtual absence of remote sensing in the technology programs in the two-year colleges.

2.2 COURSES OFFERED

About half of the courses offered are concentrated in 10 states. Ranked in descending order these are: California, New York, Arizona, Ohio, Wisconsin, Indiana, Colorado, Michigan, Tennessee and Texas. Within the mapping sciences both remote sensing and geodesy are characterized by a strong emphasis at the graduate level. Of the nearly 700 courses offered 34 per cent could be classed as remote sensing, 33 per cent as aerial photo interpretation, 12 per cent as photogeology, 6 per cent as sensor technology, and 4 per cent as image interpretation. Courses in map and aerial photo interpretation have been classified under cartography and excluded from this discussion.

2.3 PROGRAMS OFFERED

Succinct characterization of programs of remote sensing education is especially difficult as much change is occurring at present and existing programs generally are not well articulated. Data on programs are available in highly preliminary form only. Two features of remote sensing programs that emerge clearly are a graduate level emphasis and the near absence of remote sensing in two-year colleges. There is also a taxonomic problem because remore sensing education tends to be imbedded in other programs and these lack external visibility.

2.4 SHORTFALLS IN REMOTE SENSING EDUCATION

Even in a brief overview of remote sensing education such as this, one feels compelled to identify major gaps or deficiencies. One of the most glaring gaps is the near-absence of remote sensing technician training programs in American colleges. Such programs exist within the defense establishment but elsewhere commercial firms and government agencies must rely upon on-the-job training. Program specialization or vertical development is weak reflecting the well known "critical mass" problem of concentrating sufficient numbers of faculty, students and facilities to offer viable programs. The problem that the education system has of keeping abreast of technological developments in the remote sensing field grows progressively larger. The large number of short courses in remote sensing is clear evidence of a strong and expanding demand for education in this field. It is also symptomatic of the need for more formal training and of serious lags in technology transfer within the system. Lastly, one can note weakly developed linkages between remote sensing and other mapping sciences programs such as cartography and photogrammetry.

3. PROBLEM AREAS AND PRIORITIES

3.1 PROBLEM AREAS

3.1.1 Education Data Base

Until quite recently it has been virtually impossible to obtain a comprehensive view of the national system of education in remote sensing.(1) We have reached a point at which it is obvious that significant changes are needed and considerable frustration has emerged because the nature of the changes needed is not clear. It has become obvious that we lack much of the basic data needed to determine the state of the education system and how best to effect the changes needed to improve the system. The types of data needed include knowledge and skill requirements for various specialties in remote sensing, and inventory of courses and programs offered, course enrollments, numbers of students completing the programs, and access to hardware and software.

3.1.2 Career Information

Career information is needed by prospective students and other potential employees as well as by high school counselors, advisors, employers and education planners. The prospects of attracting talent are greatly enhanced by literature clearly portraying the occupational structure of the field and delineating career pathways.

3.1.3 Program Varieties and Qualities

The variety and quality of education programs available fails to meet national standards in many important respects. The client-orientation of present programs has failed to achieve the types and levels of integration needed as remote sensing attains increasing stature as an applied science. Concern continues to be expressed that existing programs have failed to provide adequate attention to topics such as: advanced principles of stereoscopy; wave propagation equations, laws and boundary conditions for reflection, refraction, transmission and absorption; advanced spatial, spectral, temporal, and radiometric resolution; advanced concepts of digital image processing;

spatial data structures; and multidisciplinary evaluation of remote sensing data requirements.(2) Clearly there is much need for program architecture to guide the development of the variety of multi-disciplinary programs that take account of institutional resources and the knowledge and skill requirements of remote sensing.

3.1.4 Weak Institutional Support

The ability of universities to support the equipment and software needs of high technology remote sensing programs continues to fall far short of minimal requirements. With little or no relief in sight, the progress of transferring remote sensing technology to state and regional levels probably will continue to lag behind expectations and needs of the national system. Within institutions there is the further problem of broadening student access to remote sensing expertise and facilities.

3.2 RESPONSES NEEDED

3.2.1 Development of an Education Data Base

With the support of the National Mapping Division of the U.S. Geological Survey, a Mapping Sciences Education Data Base has been created to support program planning and development and to provide current information to students and advisors.(3) As the data base becomes operational it is planned to publish annually a "Directory of Courses and Programs in the Mapping Sciences." With the overall knowledge of the mapping sciences education system provided by this data base it is expected that special and timely data needs can be met by sample survey methods.

3.2.2 Development of Conceptual Models

In the interests of promoting educational planning in remote sensing attention is drawn to the need to develop conceptual models because of the powerful potential they have for provoking discussion and stimulating change. Such models show in a generalized form the parts of an education system and their relationships and can be used as guides in drawing up detailed specifications in a particular context. It is important that these conceptual models be developed from requirements defined in functional terms rather than those arising from the traditions or internal logic of an academic discipline. At an early stage it would be desirable to collaborate with an advisory group from the remote sensing community. The group could provide input, not only in the development stages of modeling, but also in various evaluation stages. Implementation of the models will require new resources particularly during the initial stages. For such support the whole-hearted cooperation of professional societies will be critical. Once these models have been developed and evaluated it will become feasible to develop conceptual models for programs of continuing education.

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2. John R. Jensen and Richard E. Dahlberg, 1981. "Conceptual and Technological Development in Cartographic Education: The Remote Sensing Contribution," Technical Papers of the American Congress on Surveying and Mapping, 1981 ASP-ACSM Convention Washington, D.C., pp. 311-330; Richard E. Dahlberg and John R. Jensen, 1981. "Potential Impacts of Recent Developments in Remote Sensing Upon Cartographic Education in the U.S.," International Yearbook of Cartography, Vol. 21, 26 pp. (in press).

3. Dahlberg, 1980. Op. cit.

TABLE 1

U.S. Colleges and Universities:

MAPPING SCIENCES COURSE SUBJECT GROUP OFFERINGS

BY HIGHEST LEVEL OF OFFERING AT INSTITUTION

	2 to 4 Year	4 or 5 Year	First Professional	Masters	> Masters and < Doctorate	Doctorate	Total
Remote Sensing/API	32	19	3	78	48	511	691
Cartography	232	65	9	226	167	580	1,279
Surveying	1,316	143	15	136	71	512	2,193
Geodesy	19	8	1	7	5	92	132
Geographic Information Systems	--	--	--	2	--	21	23
Photogrammetry	59	17	1	22	5	176	280
Totals	1,658	252	29	471	296	1,892	4,598

Source: Mapping Sciences Education Data Base

TABLE 2

U.S. Colleges and Universities:

MAPPING SCIENCES COURSE OFFERINGS BY

DISCIPLINE AND BY SUBJECT GROUPS

	Remote Sensing	Cartography	Surveying	Geodesy	Geog. Inform. Systems	Photogrammetry	Totals
			CONVENTIONAL ACADEMIC SUBDIVISIONS				
Natural Resources and Agriculture	72	11	58	--	2	31	174
Engineering	130	12	510	62	4	120	838
Physical Sciences	175	99	32	27	-	26	359
Social Sciences	259	906	6	3	15	15	1,204
Other Subdivisions	17	27	20	6	2	6	78
Sub-Totals	653	1,055	626	98	23	198	2,653
			TECHNOLOGICAL AND OCCUPATIONAL CURRICULA				
Engineering Technologies	17	200	1,490	34	--	71	1,812
Natural Science Technologies	21	21	77	--	--	11	130
Other Subdivisions	--	3	--	--	--	--	3
Sub-Totals	38	224	1,567	34	--	82	1,945
Totals	691	1,279	2,193	132	23	280	4,598

Source: Mapping Sciences Education Data Base.

Session 1-B

Skills, Needs, and Opportunities in Remote Sensing: A Challenge to the Educational Community

Highlights:

Session Chairman Roger Hoffer set the stage by explaining to the audience that each panel member was asked to address two questions which would convey to the audience what they felt the ultimate driving forces of remote sensing education are now and will be in the future. The two questions were: 1) "What kinds of skills, knowledge and abilities do you look for when hiring an individual for your organization?" 2) "What do you perceive as the job market for people with a remote sensing background for the next 5 years?"

Messrs. Johnson, LeBlond, Davis and Gilbert, in turn, presented their viewpoints to the audience. The papers upon which their comments were based appear on the following pages. Following that is a summary of the discussion which took place. The paper by R. Porter was not presented but was summarized by the Chairman.

We regret that the paper by G. Johnson was not available to be included in this volume.

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SKILLS, NEEDS AND OPPORTUNITIES IN REMOTE SENSING --
A CHALLENGE TO THE EDUCATIONAL COMMUNITY

Roger M. Hoffer
Department of Forestry and Natural Resources
Purdue University, West Lafayette, IN

The number of universities offering courses in remote sensing has increased rapidly in the past few years, and the content of these courses has become more diversified as the remote sensing technology has developed. Many of us at this conference have been teaching remote sensing courses for ten years or more, while many others have just started or are about to develop a new course in some aspect of remote sensing. We represent many different disciplines, including geography, civil engineering, forestry, geology, agriculture, and others. However, we all share several areas of common concern, such as effective techniques and the availability of materials to enable us to improve the quality of our courses, the significant elements of the remote sensing technology that should be included in such courses, how to best integrate the remote sensing technology with the other subject matter being taught in our discipline area, the training needed and career opportunities for those who want to specialize in remote sensing, and many other areas of common interest that one could cite.

Our panel discussion this morning has been designed to provide a focus for some of these areas of common interest. We are indeed privileged to have with us five outstanding individuals representing federal agencies and private industry groups who are potential employers of the students whom we as educators are in the process of training. We have asked each panel member to address two questions from his respective vantage point. First, what kinds of skills, knowledge and abilities does one look for when hiring an individual for his organization? Second, what is the perceived job market for the next five years?

I am anticipating some interesting comments in response to these questions. It is my hope that the statements by the panel members will stimulate many comments, questions and further discussion of these issues both this morning and throughout the week. The opportunities for those trained in remote sensing, the skills required, and the needs of the private and public agencies who will employ our graduates indeed offer many challenges and opportunities to us as remote sensing educators, both today and in the years ahead.

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INTERNATIONAL DEVELOPMENT RESEARCH CENTRE*
REMOTE SENSING PROGRAM

Robert LeBlond

Program Officer
Information Sciences
International Development Research Centre
Ottawa, Canada

In 1973, the Information Sciences Division of IDRC began a small program dealing with remote sensing applications and the mapping of natural resources in developing countries. The aims were to provide useful assistance to research and development activities related to this field and to learn how this transfer of technology could be efficiently achieved. The appropriations for these activities amounted to nearly $750,000 (CDN) and they have been used primarily for a series of projects completed in Bolivia, Sudan, Tanzania, Mali and Bangladesh between 1975 and 1979.

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* The International Development Research Centre is a public corporation created by the Parliament of Canada in 1970 to support research designed to adapt science and technology to the needs of developing countries. The Centre's activity is concentrated in five sectors: agriculture, food and nutrition sciences; health sciences; information sciences; social sciences; and communications. IDRC is financed solely by the Parliament of Canada; its policies, however, are set by an international Board of Governors. The Centre's headquarters are in Ottawa, Canada. Regional offices are located in Africa, Asia, Latin America, and the Middle East.

The IDRC approach permitted the developing countries to play a major role in the formulation and execution of their projects. Grants covered expenditures relating to consultancies, training activities, field-work, and the procurement of equipment. Local authorities also shared some of these expenditures and had entire responsibility for the composition of the research team, the selection of the study site, the carrying out of operations and the production of maps. The five projects selected allowed a very interesting sampling in terms of objectives, institutional arrangements and levels of development.

They followed a similar pattern of activities consisting of preliminary data collection, training, field survey, data verification, and map production. However, different arrangements were used for each project, particularly for training and consultancies, depending on the requirements for such services, and their availability. Each project also produced tangible results in the form of maps for developmental purposes. Thematic small-scale maps (1:500,000 to 1:250,000) were prepared for sample areas of the Desaguadero Valley in Bolivia, parts of the Kordofan Provinces in Sudan, the Rukwa Region in Tanzania, the Sikasso Area in Mali, the Karnafuli Reservoir and the Ganges Basin in Bangladesh. Large-scale computer-prepared maps (1:25,000) were also produced for smaller sample areas in two of the projects.

The execution of these projects involved more than twenty-five researchers from developing countries, eight short-term consultants and four training institutions from Canada, U.S.A. and France. The results of this cooperative research program were presented and discussed during a workshop in Nairobi in March 1978.

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STAFF NEEDS FOR EFFECTIVE REMOTE SENSING EXPLORATION

by James R. Davis
Phillips Petroleum Company
Bartlesville, Oklahoma

Remote sensing is assuming a role in the search for natural resources. Research has shown that satellite imagery may be important in locating certain types of petroleum and mineral deposits.

Either direct or indirect indications of natural resource occurrences have to be detectible from standard or enhanced imagery data. These indications are the result of geochemical alteration of soils or geochemical stress on vegetation in affected areas as compared to the surrounding unaffected area.

Traditional mapping of geological structure can be accomplished using satellite imagery data. In petroleum exploration this may be helpful in remote underdeveloped countries, but probably will not be utilized extensively in well mapped areas such as the U. S., Canada, and Europe.

In the case of petroleum, it is generally accepted that petroleum migrates to the surface where it can interact geochemically and geobotanically. Petroleum ranging from asphalt to methane is encountered as seeps or microseeps in soils above petroleum trapped at depth. Tonal anomalies have been reported on Landsat imagery, for example, from Wyoming. It is believed that iron depletion and the presence of hydrocarbons in the soil over the Patrick Draw field may be the cause of the stressed sagebrush at that location (N. L. Froman, 1976 and R. W. Marrs and R. Gaylord, 1981). At other locations such anomalies have been attributed to development roads and well locations developed after the discovery of an oil field.

Tonal anomalies in Railroad Valley, Nevada provide an interesting case for the use of enhanced imagery to clarify an anomaly. Oil was discovered in the Eocene at 4000 feet below the valley floor. The anomalies do not coincide with the outline of the known production. This case would provide a good case to investigate both geochemically and geobotanically.

In the case of minerals exploration certain correlations have been made between mineral occurrence and vegetal stress. Reimer (personal communication) has noted that larger sagebrush is found over near surface uranium deposits. Also, stunted conifers have been noted in association with cobalt and nickel mineralization in ultramafic rocks. If these differences are detectable from satellite imagery, then they can be used to delineate mineralized zones on the surface.

The purpose for being here is not to present documented cases of the use remote sensing for natural resource evaluation, but to indicate the type of qualified people that will be sought after by industry. The disciplines are generally in three areas: (1) geologists, (2) organic and inorganic geochemists, and (3) geobotanists.

The role of the geologist is to field check imagery data, gather ground truth data and samples, interpret imagery data, and to be adept in the use of computer hardware and software used in enhancing imagery data.

The geochemist's role is to investigate the chemistry of soils to establish relationships between anomalies recognized from remote sensing data to chemical anomalies on the ground.

The geobotanist's role is to correlate abnormal plant development to the anomalies recognized on imagery data.

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Skills, Needs, and Opportunities in Remote Sensing
A Challenge to the Educational Community

Richard H. Gilbert
U.S. Department of Agriculture, Soil Conservation Service

The U.S. Department of Agriculture has been a user of remotely sensed data for more than four decades. Every agency in the Department that has a responsibility to measure, estimate, monitor, or manage the natural resource base of our country uses remote sensing methods or data to some degree. Even the Department's estimates of world food production are based in part on the evaluation of Landsat data.

There is no doubt that the Department's remotely sensed data will increase, but two facts should be kept in mind. First, USDA employees who use remote sensing to help them do their job are agricultural specialists of one kind or another: soil scientists, foresters, statisticians, and others. Very few are hired as remote sensing specialists. Second, the interpretation of visual images remains the most common kind of remote sensing activity in the Department, but computer-aided analysis of multispectral scanner (MSS) data has increased considerably in the past 3 to 5 years.

MSS data from the Landsat group of satellites have been investigated by people in many different disciplines. USDA agencies routinely analyze Landsat scenes for estimating domestic as well as foreign crop production forecasts. Landsat is not the only source used to make these forecasts, but it is being used with good results.

The Forest Service is using Landsat data, high-resolution photography, and statistical analyses to conduct multilevel inventories with a high degree of accuracy. On Forest Service land that is steep, rough, and remote, ground inventories can be difficult and time-consuming. These kinds of areas are ideal for remote sensing activities. Time savings and accuracy of the data are proving these methods to be cost effective.

For several years the Soil Conservation Service has been developing techniques to use Landsat MSS data as an aid to field soil surveyors. Aerial photography and specially prepared Landsat maps make it possible to save time and increase the quality of the survey. There are, of course, limitations of the use of Landsat maps, but they show promise in some parts of the country.

The Beltsville, Maryland Hydrology Lab of the Department of Agriculture, Science and Education Administration is studying the use of remotely sensed data for measuring soil moisture. The data will be used to forecast watershed runoff by various modeling methods. Both Landsat and microwave sensors are being studied for this application.

There are other examples of the use of remote sensing in the Department, but nearly all of them involve photointerpretation or MSS data analysis.

There are three areas of study important for specialists who use remote sensing. The first area is sensor awareness. This means that students who receive remote sensing training should be aware of the many different types of sensors that are available and in use. They should know the capabilities, limitations, and major application of these sensors.

The second area is the study of current trends in research and development. Which sensors and analysis techniques can today's student expect to work with in the future? The student should learn what is happening in the development of new ways to gather remotely sensed data and what are the potential uses of the data.

The third area is present-day operational applications of remote sensing technology. It is important for remote sensing educators to incorporate this area in their courses if students are to become trained remote sensing specialists who can compete in the job market by meeting present-day challenges in the public and private sectors.

Future job opportunities appear good for persons well trained in remote sensing. The Department of Agriculture will in all probability continue to expand its use of remote sensing, but it is worth repeating that the Department hires persons who have training in specific agriculture-related fields. If they have remote sensing training in addition to their specialty, this would be a definite advantage. The agencies in the Department are agreed that remote sensing is a very useful tool in conducting many jobs. With the budget and manpower restrictions that we are facing, we must become very efficient in the use of available resources.

The use of remote sensing is a good example of substituting efficient technology for manpower. I feel that the future looks good for well qualified specialists with supplemental training in remote sensing.

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SO YOU WANT TO WORK FOR A CONSULTING COMPANY?

J. Robert Porter, Jr.
President, Earth Satellite Corporation
Washington, D. C.

Today I'd like to tell you something about our company, the type of employee we recruit, and the factors that bear on the recruitment process.

EarthSat is involved in the application of remote sensing technology to a wide variety of resource inventory and monitoring programs. We were founded in 1969 and, at present, employ approximately 80 individuals. Our staff is made up of natural scientists, technicians and administrative staff. Approximately two-thirds of our staff have degrees in the natural sciences; 25% have advanced degrees. Our business is primarily directed at the application of established technologies. Our business is, by-and-large, consulting support and provision of products to industry and government; two-thirds to three-quarters of our contract work is for private industry. The balance is for both Federal and State governments. From time-to-time we work for foreign governments.

Our business divides into four principal areas: The first is computer processing of Landsat data for a wide variety of applications. This work involves computer scientists, photo laboratory technicians and natural scientists for the various disciplines who have a need for specially processed and enhanced Landsat data. The second area involves agricultural forecasting and meteorology. We employ meteorological satellite data, Landsat data and a number of EarthSat-developed computer models to provide regular worldwide production forecasts of major commodities for clients throughout the world. The third area, geologic exploration, involves, with few exceptions, private clients who are seeking new deposits of minerals and petroleum. The majority of this business is domestic for North American petroleum companies. Finally, our Land Resources and Environmental Applications Divisions are involved in a variety of resource mapping projects throughout the world using remotely sensed data that ranges from Landsat imagery to low altitude aerial photography. All the projects we conduct using remotely sensed data also involve substantial amounts of field work.

New employee hiring for us is the single most important investment decision we as a corporation make. What would an honest and realistic ad look like?

> WANTED: A specialist with strong academic background, preferably graduate training and two years experience in geology, agronomy, geography or computer science. Must be bright, self-confident and personable, adaptable to changing circumstances, able to manage and be managed, to take and to give criticism, to think and to do, to express himself or herself well and to listen, to assert himself persuasively and care about others, to enjoy travel and new experiences, to be intellectually curious and have an infectious enthusiasm, to be able to survive disappointment and withstand the ups and downs of a small company. Foreign language desirable, but not required. Minimum commitment by employee - 2 years, but subject to release at any time.

Is this asking too much? I don't think so. Let's look at the requirements one by one:

First and foremost, we look for an applicant who has a strong academic background in his major discipline. For example, in geology we look for candidates who have a strong general training and are interested in the exploration process. With young candidates who have very little track record, I ask myself the question, Has this person ever done anything in depth? Has he or she shown any indications of falling in love with this or any subject? How did he or she come to be interested in geology to begin with? Can he or she identify a few issues that particularly interest him, and when he identifies an issue, what has he done to pursue it? The same approach applies to other disciplines as well. By the time a person is 22 or 23 years old he has had an opportunity to pursue <u>something</u> in depth, even outside his discipline, and if he hasn't by then, I think he's a poor bet. I believe the world can be divided into two categories of people - thinkers and non-thinkers. The propensity to think starts at a very young age, and is quite independent of one's academic credentials. You can ask a thinker, "What did you learn yesterday, or last week?" and he will be able, on reflection, to give you a few examples. Most people fail this test.

Second, I look particularly for native intelligence and sensitivity to others. Being intelligent is much different than being a thinker. Intelligence, as I mean it, relates to one's aptitude to assimilate new information and in turn very much bears on a person's self-confidence and willingness to listen to a customer's problem. The more limited one's intelligence, the more likely he will be confined to taking the "let me tell you" approach because he is uncomfortable when he's on unfamiliar ground. Intellect also bears on a person's ability to manage or be managed, or whether he can take or give criticism. A new employee at EarthSat is put on a very fast track. His peers are generally much brighter and more experienced than average. Nevertheless, it is our habit managerially to operate more as a partnership than a highly structured hierarchy. This means that at any one time an employee will be a worker on one project, while simultaneously being a manager on another. Consequently, the man in the next office may both be reporting to you and you reporting to him at the same time.

Third, flexibility and adaptability are important. We are in a rapidly evolving technology where an individual cannot coast comfortably along on last year's skills and knowledge. Learning is a continuing process.

Fourth, a critical consideration for a small consulting company is the ability to survive disappointment. Let's face it -- the customer is very often less knowledgeable than we, in our field of expertise, but expects us to be thoroughly conversant in his field. There are certainly many instances where what we believe is best for the customer is different from what the customer believes is best for himself, and the way we would like to orient a project is not the customer's preferred direction. Naturally, this is disappointing, but you can't let it get you down. After a while, a new employee develops the skills and becomes more adroit at asserting himself while still meeting his customer's requirements.

Finally, there is a level of uncertainty in a small company which scares off many. To be perfectly honest, we have had some very hard times over the 12 years of our existence. We have always made our payrolls, but sometimes not by much, and there have been times when we've had to temporarily cut employee's salaries or cut off activities we really believed in, but could not afford to support. On the other hand, we're extremely candid with our employees so that at least they don't think we're hiding problems from them. I always make a special point of discussing this issue with potential employees. First because it's the honest thing to do, and second, because if this bothers them, they probably shouldn't work for us or any small company (or, for that matter, a large company where reductions in staff are more frequent and less tied to individual contribution).

You may have noticed I did not set a requirement "be able to sell." That's because selling at a professional level is accomplished primarily by doing a solid technical job and being able to communicate to the client. Nor, even more surprisingly, did I mention that preference would be given to persons with a background in remote sensing. This is because I believe this is a skill which can be learned on the job. Finally, I did not mention photointerpretation experience per se. Once again, this is because it is a specific skill. However, prior experience is helpful to establish that the employee knows what he is getting into and feels he is temperamentally suited for that kind of work. It also convinces clients that we are well qualified in our field.

In conclusion, the best thing I can say about this process is that it works. On the occasion of EarthSat's 10th anniversary, fifty percent of our staff had been with us for a 5 year period. Further, while we do pay reasonable salaries, give bonuses, stock options, interest in oil royalties, etc., these can all be obtained from other companies if a person is really good. On the other hand, what we would like to feel that we do particularly well is provide a thoroughly professional atmosphere so that our staff enjoys their job and their associates. I guess it works. A lot of business is directed to us by ex-employees.

Reacting to the remarks of several of the speakers, a participant in the audience raised the question whether the current attitude of employers who consider remote sensing skills to be secondary compared to a solid education in one of the traditional discipline areas was a result of what was presently available in the pool of available talent. Panelists responded by saying that remote sensing is a relatively new discipline and that this attitude might change as the talent pool builds up. Another panelist said that in five years they would still be looking for strength in the traditional disciplines (geology, geography, agronomy, ...).

A question from the audience was addressed to Dr. Davis asking him whether his company specifically looked for remote sensing training and background when hiring. Dr. Davis said that it would be easier if a person with a remote sensing background were available but that it was not a requirement.

"What percentage of applicants have remote sensing qualifications" was asked by a member of the audience. Responses were: Davis - few of our applicants; Gilbert - haven't seen any remote sensing specialist applicants; Johnson - 80% of resumes show some experience but it varies widely.

Dr. Philip Swain, LARS, remarked that he currently heard a number of executive-level engineers remark that they considered the following factors to be extremely important when hiring: 1) communication skills, 2) technical competence, 3) retreadability and 4) the human factor (ability to interact at the conceptual level both up and down the chain of command). He asked the panelists to rank the importance of these factors to them. Johnson replied that 1 and 4 could be grouped together and his ranking would be 1-4, 2, 3. Gilbert agreed.

Question from the floor - "Where do you advertise?" Responses: Gilbert - Office of Personnel and Management; Johnson - University mailing list, ASP journal; Davis - trade journals and selected universities.

A question came from the audience as to how best to counsel, say, a junior undergraduate who shows interest in remote sensing. Should a BS followed by an MS with an emphasis in remote sensing be recommended? Johnson said that the summer student intern program at the EROS Data Center provided excellent experience for students.

A question was address to Gilbert as to the present role of universities in AgRISTARS (a current NASA research program). Gilbert responded by giving a brief background on AgRISTARS and stating that the role of Universities was primarily that of research.

A member of the audience reminded everyone that Universities need good people too.

The chairman closed the session by pointing out that a common thread in the presentations and discussion was that there is a perceived need for people with a solid background in one of the traditional disciplines (perhaps at the BS level) plus additional work or experience in remote sensing (perhaps at the MS level).

Session 2-A

Resources and Strategies for Teaching Remote Sensing

Highlights:

Session 2-A had two papers addressing some general aspects of the teaching of remote sensing. The first paper surveyed sources of material while the second paper dealt with equipment and approaches for teaching visual interpretation. Opening comments were made by session chairman Tom Lillesand. The two papers appear on the following pages.

NASA

CORSE-81

The 1981 Conference On Remote Sensing Education
May 18-22, 1981 Session No. 2

SURVEY OF INSTRUCTIONAL MATERIAL FOR REMOTE SENSING

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The variety of materials produced in the last ten years for remote sensing education testifies to the rapid growth of these technologies not only in the terrestrial sciences, but in medicine, law, materials testing, atmospherics and interplanetary surveys. For the earth sciences a recent compilation by Dr. Richard Dahlberg lists some 960 institutions of higher learning and over 1600 academic departments offering courses in the mapping sciences. Included in his list are approximately 700 courses in remote sensing. This indicates an explosive increase in formal educational opportunities since the review by Nealey in 1976. By comparison Nealey reported 454 remote sensing courses at 24 universities.

In its broadest definition remote sensing is a process that draws upon our knowledge of electro-optical engineering, computer sciences, statistics, photochemistry, and a host of cultural and physical sciences. As the techniques become more widely accepted, an even broader sector of our economic and social lives will be embraced. We are already beginning to find social and economic models combined with remote sensing data in the design of geographic information systems. It is not surprising, therefore, that existing educational materials reflect this breadth. We know of at least 36 remote sensing newsletters published by a variety of federal, private, international and university groups. They keep us informed of project status, launch plans, system developments and more meetings, symposia, seminars and short courses than at first appear to be reasonable. The point is that our once rather small community of generalists has grown and diversified into a series of technical specialties. According to a report from Public Technology Incorporated (PTI) there are more than 150 remote sensing product and service organizations currently operating in the United States, many of them offering batch and interactive digital image processing, visual interpretations, processing software, or hardware. The "industry" is growing and appears to have increased vitality during economic cut-backs. Many employment opportunities for today's earth science graduates require not only the traditional discipline-oriented knowledge and skills, but a functional understanding of electro-optical sensors, data processing techniques and interpretation strategies.

Tables 1 and 2 refer to the contents of 17 major textbooks and reference guides. There are numerous additional sources that should have been included, had time and access permitted. Hopefully, many of these are on display at the conference. For materials other than texts I refer readers to Bryan, 1979 and the compilation by Budge for the American Society of Photogrammetry Committee on Education, 1981.

It is certainly an error to compare the numbers of pages devoted by authors to given topics, but in this crude manner we can at least see the diversity of their interests and approaches. First of all, it is fairly evident by comparing Tables 1 and 2 that, as a group, these books concentrate more on principles of the electromagnetic spectrum, sensors and data processing, than on applications. Recent notable exceptions include, for the geological sciences, Sabins, 1978, and Siegal and Gillespie, 1980; and, for cultural resources, Lyons and Mathien, 1980. For well-rounded treatments of the systematics of remote sensing, Lillesand and Kiefer, 1979; Lintz and Simonett, 1976; Sabins, 1978; and, Siegal and Gillespie, 1980 appear to be most comprehensive.

Secondly, if we scan the columns by topic, it appears that basic photo interpretation receives considerable attention, but that photogrammetry does not. It is probably still true that many students who receive instruction in remote sensing have no prior training in such landmark texts as Avery, 1968; and, for this reason, some space must be devoted to developing these skills. Interestingly, there seems to be about the same amount of space for analog and digital image processing. Relatively new books by Bernstein, 1978; and Swain and Davis, 1978 are devoted essentially to digital image processing and there are others not included here by Tou and Gonzales, 1979, Gonzales and Wintz, 1979 and Gonzales and Thomason, 1978. I think it is safe to presume that other works now in progress will reflect greater degrees of specialization.

There can be little question but that the engineering and computing sciences still dominate the bulk of what is written in remote sensing. Data interpretation and information inputs into systems for resource management lag far behind; not because the work is not being done, but because the user community is so dispersed that textbook quality examples are hard to find. The geologists have begun to breach this barrier and one can hope that the biological and geographical communities are not far behind.

TABLE 1: SPECTRUM, SYSTEMS, SENSORS AND PROCESSING

REFERENCE (alphabetical by 1st author)	Introduction (Principles & Concepts)	Electromagnetic Spectrum and Camera Systems	Photogrammetry	Basic Photo Interpretation	Multispectral Scanners	Thermal Scanners & Thermography	Active & Passive Microwave	Analog & Digital Image Processing	Satellite Systems & Sensors	Glossary	Miscellaneous
AMER. SOC. PHOTO (1975/2061)	229	403		342			136	8		50	
BARRETT & CURTIS (1976/323)	68	20		32				21	10		9
BERNSTEIN (1978/457)								457		7	
ESTES & SENGER (1974/329)	22	15						32		8	15
HOLTZ (1973/390)	93			112*	37	34	74				29
JOHNSON (1969/219)	17			115*		10*					
LILLESAND & KIEFER (1979/603)	35	104	52	94*	46	59	40	26	46		
LINTZ & SIMONETT (1976/627)	134	100		30	25		97	38	26		32
LYONS & MATHIEN (1980/386)											
NAT. ACAD. SCI. (1970/420)	34	37	25				54	96			
RICHASON (1978/441)	15	18		48			30		38		
RUDD (1974/125)	21	118		24*					39		20
SABINS (1978/402)	16	30		15	18	58	46	42	12	10	
SIEGAL & GILLESPIE (1980/687)	117			42		40	66	110		8	
SLATER (1980/559)	307								79		12
SWAIN & DAVIS (1978/386)	133							239		11	
WENDEROTH & YOST (1974/200)	63	115		18						4	

* Includes discussion of interpretation techniques for a variety of terrestrial applications.

TABLE 2: REMOTE SENSING APPLICATIONS

REFERENCE (alphabetical by 1st author)	Terrain Analysis	Land Use	Agriculture/Forestry/Range	Geology	Resource Exploration	Water Resources	Environmental Quality/Hazards	Oceanography	Meteorology	Cultural Resources	Urban Studies	Other
AMER. SOC. PHOTO (1975/2061)	49		211		81	66		63	88	57	107	155
BARRETT & CURTIS (1976/323)			35	40		22			52		13	
BERNSTEIN (1978/457)												
ESTES & SENGER (1974/329)		22	66	22			10				52	
HOLTZ (1973/390)												
JOHNSON (1969/219)						12						25
LILLESAND & KIEFER (1979/603)	95											
LINTZ & SIMONETT (1976/627)			41	64		21		34		20		
LYONS & MATHIEN (1980/386)										386		
NAT. ACAD. SCI. (1970/420)			163									
RICHASON (1978/441)	24		48						24		78	8
RUDD (1974/125)		3	10									
SABINS (1978/402)		8		37	45		20	19				
SIEGAL & GILLESPIE (1980/687)				122	120	28	24					20
SLATER (1980/559)												
SWAIN & DAVIS (1978/386)												
WENDEROTH & YOST (1974/200)												

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Johnson, P.L. 1969. Remote Sensing in Ecology. University of Georgia Press. Athens. 219 pp.

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Lintz, J., Jr. and D.S. Simonett. 1978. Remote Sensing of Environment. Addison-Wesley. Reading, Mass. 714 pp.

Lyons, T.R. and F.J. Mathien. 1980. Cultural Resources Remote Sensing. National Park Service. Washington. 390 pp.

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Sabins, F.F. 1978. Remote Sensing Principles and Interpretation. W.H. Freeman. San Francisco. 402 pp.

Siegal, B.S. and A.R. Gillespie. 1980. Remote Sensing in Geology. John Wiley. New York. 687 pp.

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CORSE-81

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Equipment and Approaches for Teaching Visual Image Interpretation

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Introduction

This presentation will consist of two major parts: (a) a summary of equipment needs to get one started in teaching a visual image interpretation course, and (b) a summary of lessons learned from experience with multimedia and programmed teaching approaches. The Conference on Remote Sensing Education in 1978 presented much of what might be included here. The proceedings of that Conference (Welch, 1980) has much information and food-for-thought which has probably not yet been digested by the remote sensing community. I recommend it to all of you.

Equipment Needs

The equipment and aids needed for starting a visual image interpretation course fall into the general categories of: (a) viewing, (b) image enhancement, (c) measurement, and (d) transfer.

Presented in Table 1 is a list of basic equipment necessary for different types of image interpretation courses, range of costs, and a few characteristics and uses. In Table 2 is a list of sources where these items may be procured. Many of the major texts and manuals in remote sensing list and explain these, for example, Reeves, 1975 pp. 897-909, Colwell, 1960, pp. 148-168, Slama, 1980, pp. 535-541, Lillesand and Kiefer, 1979, pp. 99-112, and Cimerman, 1970.

The last few columns in Table 1 tell in what types of courses--basic advanced photo interpretation, or remote sensing for domestic, continuing education or foreign situations--the item is necessary or desirable. Of course not all types of equipment are listed, and some judgment must be used in interpreting the comments for any particular situation.

Besides these items of equipment, many other materials may be necessary for a good course: e.g. acetate or overlay material, lamps for good lighting, a point picker (teasing needle), various pens, a soft drafting eraser, masking tape, and a calculator.

Selected comments on equipment and materials

As you can see from Table 1 the very basic items needed for a beginning interpretation course are: a pocket stereoscope, linear, area and height measuring devices, a transfer device and a 35 mm overhead transparency projector for presentations. I have just a few comments on experiences, relating to the equipment and materials, which we have learned over the years.

You can purchase relatively cheap plastic or cast aluminum stereoscopes, but I recommend one of stamped aluminum construction. It costs about $18-25, and its useful life is 5 to 10 times that of plastic or cast aluminum.

A good measuring scale is a necessity. A transparent ruler with both metric and English units (in tenths) is very useful. The dot grid and parallax wedge can easily be produced by drafting the details at a four-times enlargement and then reducing it photographically onto Kodalith. The average cost can be kept to approximately $1 each.

In respect to other material items needed for a course, I would recommend the use of the Pilot SC-UF Ultra Fine Point Permanent pen for marking on photos and transparency materials. A study of ours (Ulliman and Grah, 1980) found it better for general lab and field work than even the technical drafting pens.

For those teaching remote sensing (especially LANDSAT) in foreign areas, you might be interested in an article by Frederic Hilwig (1979) which describes the practical methodology of visual interpretation using multispectral and multitemporal data. He also tells what equipment is necessary to do this. If you wish to make a color additive viewer for less than $20, read Richardson (1978).

Bob Heller taught a six week remote sensing workshop in China last spring and discovered an interesting and effective way of transferring information from LANDSAT to maps. The Chinese used a copy camera with a one-meter square back-lighted frame to transfer 1:250,000 LANDSAT delineations onto their 1:200,000 maps. Since the frame could be tilted, they could easily register the entire image and then transfer information in one set-up, while most other transfer devices require multiple set-ups.

Lessons learned from experience with multimedia and programmed teaching machines

There are two general ways I have taught the basic aerial photo interpretation course: (a) by the standard structured lab presentation method, and (b) by using self-teaching synchronized slide tape programs. In respect to learning: (a) there are those who have the capability, motivation and responsibility to learn, whether in a structured lab or in a self-taught AV lab, (b) there are those who call for assistance and must be helped at every step, and (c) a large group falling between these two extremes who can use some assistance along the way. Programmed instruction is appropriate chiefly for the first group; but I have found, after teaching each method to approximately 80 students each of eight terms, that most students need the closer personal interaction with an instructor that a structured lab provides--especially in an image interpretation course, where a student learns by doing. Only a few students have the discipline to practice interpretation in competition with all the other demands on their time.

Programmed instruction, self-learning programs, teaching aids, etc. are important, but the student must do the work and think about the procedures. For that reason I would like to reiterate the advantages and disadvantages of instructional technology as I presented them two years ago.

Advantages

It has been shown in many studies that students can learn effectively with new instructional technology methods and media. Some of the reasons for this are: (a) greater variety of methods and messages are possible; (b) greater variety may motivate some students who may not otherwise have been inspired; (c) students can get more involved in the learning process; (d) it may help to improve the teacher because the use of instructional technology requires more exacting work; (e) it can bring renowned instructors into the program through the use of audiovisual aids; (f) it can keep material current with audiovisual aids; (g) teachers can reach a greater audience; (h) more responsibility to learn is put on the student where it belongs.

Limitations

There are also possible drawbacks to the use of instructional technology that we should be aware of: (a) as instructors we may lose personal contact with the students; (b) some students may lose motivation because of the loss of personal contact--some may not take the responsibility to learn; (c) costs may be high for equipment, materials, and programming; (d) much planning is necessary; (e) if instructors tie themselves too closely to the use of media and teaching machines they may lose flexibility; (f) we cannot assume a student has learned once he has viewed a slide/tape program. There must be a "change in behavior", and feedback; (g) AV media may not be appropriate for some topics and for some students.

I would like to emphasize the last four words, which I added since CORSE '78. Students have made this known to me in two ways: (a) a majority of students indicated in their teacher/course evaluations that they did not have enough incentive to do the self-learning labs; and, (b) many students lack some very basic abilities which we tend to assume in every college student--they do not know basic algebra (e.g., how to cross-multiply) or how to spell (I have gotten 33 different spellings of FIDUCIAL)! So I have returned to giving structured labs, where I can see exactly what the student is doing and what the student understands, and therefore can assist better where it is really needed.

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Table 1. Visual Image Interpretation Equipment and Aids

Equipment and Aids	Cost ($)	Characteristics	Uses	Necessary (1) or Desirable (2) in: Basic Photo Interpretation			Advanced Photo Interpretation			Remote Sensing		
				Dom	CED	For	Dom	CED	For	Dom	CED	For
1. Viewing												
a. Stereoscopes												
1) Pocket	15-100	2x and 4x mag.	best for field and training	1	1	1	1	1	1	1	1	1
2) Mirror	350-2000	1x to 8x mag.	best for office work	2	2	2	2	2	2	2	2	2
3) Scanning	2500-7800	1.5 to 9x mag. scans X and Y	good for scanning image				2	2	2			
4) Dual mirror	3450-4000	1.5 and 3x mag., allows simultaneous viewing by two interpreters	good for training	2	2	2	2	2	2	2	2	2
5) Zoom	2500-7000	2.5x to 120x mag.	high magnification; other special capabilities				2	2		2	2	
b. Magnifiers												
1) Reading	5-235	1.5x to 30x mag.		2	2	2	2	2	2	2	2	2
2) Zoom microscope	175-5000	10x to 210x	for high magnification							2	2	
c. Light tables												
1) Trans. illumin.	60-375	many different sizes	for viewing transparencies	1	1	1						
2) Standard light table	150-5000			2	2	2	1	1	1	1	1	1
3) Optical interpretation table	5000-10000	12"x30" surface, quality light source motorized take up reels, split surf.	especially for roll transparency film of variable size				2	2	2	2	2	
d. Audio Visual												
1) 35 mm projectors	150-500	various lenses	for projecting 35 mm slides	1	1	1	1	1	1	1	1	1
2) Overhead proj.	200-325		for projecting material from transparencies	1	1	1	1	1	1	1	1	1
3) *3-D projectors*	800-2500	*capable of registrating two images*	*large audiences can view 3-D*	2	2	2	2	2	2			
2. Enhancement												
a. Diazo	500-12000	Makes color transparencies; map and ortho duplication	for making color composites from 70mm or 9 inch transparencies							2	2	2
b. Color additive viewer	10,000-15,000	4 projectors, 3 color filters, interpretation table, 3.3x to 13.5x mag.	for producing color composites from 70mm				2	2	2	2	2	2
c. Density slicer	10,000-20,000	TV imaging of any size and type film product; images scene density levels as 8 or more colors; measures area	scene classification and area measurement							2	2	
3. Measurement												
a. Linear Devices												
1) Engineers triangular scales	5-45	6 scales with various divisions for English and metric	for straight line measurement	1	1	1	1	1	1	1	1	1
2) Two level plotting scales	10-25	scales in English or metric	for straight line measurement	2	2	2	2	2	2	2	2	2
3) Map measure	10-70	various units	for measuring irregular lines	2	2	2	2	2	2	2	2	2
4) Tube comparators	30-45	6x to 12x; recticle available	for comparison and measurement				2	2	2	2	2	2
5) Rapid comparator or microrule	25-275	microscales	for making fine measurements				2	2	2	2	2	2
6) Aerial photo scale and protractor	1-5	various scales graduated in chains or other units; has various plot sizes and a protractor	for determining scale on a photo, for laying out certain size plots and determining angles	1	1	1	1	1	1	2	2	2
7) Transparent rules & scales	.30-2											
b. Area Measurement												
1) Dot grid	1-5	may be designed for certain scales and format sizes	for estimating area	1	1	1	1	1	1	1	1	1
2) Polar planimeter	80-980	available in English and metric	for measuring area	2	2	2	2	2	2	2	2	2
3) Graphics calculator	2000-5000	measurement unit is programmable; modes for area, length & coordinates	for measuring area, length, digitizing	2	2	2	2	2	2	2	2	2
4) Digital planimeter	15,000	automatic area calculations with digital readout and printout	for measuring area	2	2		2	2		2	2	
c. Height Measurement												
1) Parallax wedge	1-10	designed for English or metric units	for determining the difference in height	1	1	1	1	1	1			
2) Parallax bar	60-235	for pocket or mirror stereoscope, usually metric units	for determining height difference	2	2	2	2	2	2			
4. Transfer Devices												
a. Vertical Sketchmasters	600-2400	*minimum magnification*, removes some displacement	*for transferring information* from one medium to another	1	2	2	1	2	2			
b. Optical Reflecting Projectors	1000-4000	.2x to 5x mag., table and overhead models	for transferring information from one medium to another	2	2	2	2	2	2	2	2	2
c. Zoom Transfer Scope	5000-9000	0.6x to 14x mag., removes some displacement; has stereo capability	for transferring from one medium to another	2	2	2	1	1	1	1	1	1

Table 2. Visual Image Interpretation Equipment Suppliers.

Abrams Instrument Corporation
606 East Shiawassee Street
Lansing, MI 48901

Air Photo Supply, Corp.
158-PE South Station
Yonkers, NY 10705

Alan Gordon Enterprises, Inc.
5362 Cahuenga Blvd.
North Hollywood, CA 91601

Art-O-Graph, Inc.
529 South Seventh Street
Minneapolis, MN 55415

Audio Visual Educational Systems, Inc.
6116 Skyline Dr.
Houston, TX 77027

Bausch & Lomb
1400 N. Goodman St.
Rochester, NY 14602

The Ben Meadows Company
3589 Broad St.
Atlanta, GA 30366

C-Thru Ruler Co.
6 Britton Drive
Bloomfield, CT 06002

Cartographic Equipment Sales
34621 Merlin Place
RR #4
Abbotsford, B.C.
Canada V2S 4N4

Centerline Photo Supply Company
3812 Central Avenue S.E.
Albuquerque, NM 87108

E. Coyote Enterprises, Inc.
Rt. 3, One Coyote Circle
P.O. Box 1119
Mineral Wells, TX 76067

DeHavilland Aircraft Co.
Toronto, Ontario
Canada

Dimensional Television Corp.
13720 Riverside Dr.
Sherman Oaks, CA 91423

Dot Products, Inc.
P. O. Box 1482
Cupertino, CA 95014

Edmund Scientific Company
101 E. Gloucester Pike
Barrington, NJ 08007

Fairey Surveys, Ltd.
Research and Instruments Div.
Reform Road, Maidenhead
Berkshire, SL6 8BU
England

Forestry Suppliers, Inc.
Box 8397
205 W. Rankin Street
Jackson, MS 39204

Galileo Corp. of America
36 Church St.
New Rochelle, NY 10801

Interpretation Systems, Inc.
6322 College Blvd.
Overland Park, KS 66211

Philip B. Kail Associates, Inc.
1601 Eliot Street
Denver, CO 80204

Keuffel and Esser Company
20 Whippany Road
Morristown, NJ 07960

The Lietz Company
1124 E. Del Amo Blvd.
Carson, CA 90746

Nikon, Inc.
623 Stewart Avenue
Garden City, NY 11530

Numonics Corporation
418 Pierce
Lansdale, PA 19446

Realist, Inc.
Megal Drive
Menomonee Falls, WI 53051

The Richards Corporation
1545 Spring Hill Road
McLean, VA 22101

Spatial Data Systems, Inc.
Box 249
508 S. Fairview
Goleta, CA 93017

Spectral Data Corp.
112 Parkway Drive S.
Hauppauge, NY 11787

Stratex Instrument Company, Inc.
P.O. Box 27677
Los Angeles, CA 90027

System 101 International Imaging Systems (I^2S)
650 N. Mary Ave.
Sunnyvale, CA 94086

Top Flight, Inc.
1001 Enterprise Ave.
Bay 22
Oklahoma City, OK 73128

Wild Heerbrugg Instruments, Inc.
465 Smith Street
Farmingdale, NY 11735

Carl Zeiss, Inc.
444 Fifth Ave.
New York, NY 10018

Session 2-B

Panel Discussion: Requirements of Teaching an Interdisciplinary Technology; Considerations in Course Design from Various Discipline Perspectives

A panel, chosen to represent many of the major disciplines in which remote sensing is taught, reviewed the teaching of remote sensing from their perspectives. Dr. Lillesand's opening comments, which follow, set the stage for the presentations and ensuing discussions.

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The 1981 Conference On Remote Sensing Education
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Panel Discussion: Requirements for Teaching an Interdisciplinary Technology

Panel Chairman

Thomas M. Lillesand
University of Minnesota
St. Paul, Minnesota 55108

Panel Participants

Marion Baumgardner - Purdue University - Agriculture
Ralph Kiefer - University of Wisconsin - Civil Engineering and Water Resources
Philip Swain - Purdue University - Electrical Engineering and Interdisciplinary
Merle Meyer - University of Minnesota - Forestry and Range Management
John Estes - University of California at Santa Barbara - Geography
Floyd Sabins - Chevron Oil Company and UCLA - Geology

Representing the major disciplinary contexts within which remote sensing is taught, the above panel participants presented their views of the status of remote sensing education in their respective areas of expertise. Their presentations ranged from detailed discussion of the content of individual courses, to identification of general philosophical changes needed in course and curriculum emphasis in the various disciplines.

The panel presentations and subsequent discussion helped provide a focus on the commonalities and differences among the disciplines in terms of their educational requirements. At the same time, the panel helped crystallize some of the pressing educational needs that are not being met at the present time.

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INVENTORYING AND MONITORING AGRONOMIC RESOURCES

Marion F. Baumgardner
Agronomy Department and
Laboratory for Applications of Remote Sensing
Purdue University

Value of Agronomic Information. Information is a valuable commodity! Nowhere in any agricultural science curriculum have I seen a course whose primary objective is to provide training to improve the flow of accurate, useful, timely information to decision-makers and policy-makers in the production/distribution chain for food and fiber. Of the dilemmas which confront the human family, perhaps none is more critical than that of a shrinking and deteriorating land base for food production. Many of the essential local, regional and national decisions to reverse these trends cannot be made rationally without having better information than is now available about the quantity and quality of land and water resources for food production.

The dramatic advances over the past two decades in the information sciences include a broad array of data acquisition devices, data analysis and interpretation techniques, and information dissemination methods. No agricultural scientist should be graduated from a university today without exposure to the information technology which has the possibility to provide significant improvements and frequent updates on land, crop, range, forest and water resources at a local, national and global level.

The perceived need to include an information technology course in the Agronomy curriculum at Purdue University prompted us to propose a new course entitled "Inventorying and Monitoring Agronomic Resources" (Agronomy 545). The following questions were considered in the formulation of the course objective and design.

- Who will or should enroll in the course?
- Who should teach the course(s)?
- Where should it be taught?
- What should be taught?
- What are the most effective teaching methods?

Course Objective. The objective is (a) to study the information requirements for the development and management of agronomic resources and (b) to examine new technology, hardware and software, as it relates to the delivery of more accurate, timely, useful resource information to decision-makers.

Course Structure and Design. The course provides 3 credit hours over a 15-week semester with 30 hours for presentation of subject matter (2 hours per week) and 30 hours for practicals or workshop (2 hours per week).

The course is designed as a dual level one, for upperclass undergraduate and graduate students. Since the main emphasis will be on information technology related to agronomic resources, majors in various agronomic options are expected to provide the majority of students enrolled in the course. However, any student who has an appreciation for the variations in the landscape, an understanding of the dynamics operating in the scene and an interest in inventorying and monitoring these variations will be encouraged to take the course.

The course will be taught in the Department of Agronomy and will provide "hands-on" experience in the operation and use of instruments and machines for visual and numerical analysis of remotely sensed data.

General Course Content. Although remote sensing will play a prominent role in this course, it will be treated only as a valuable tool in providing information about agronomic resources. The approach in lecture and laboratory will be to examine current and potential methods of acquiring, analyzing, interpreting and utilizing agronomic data. The following outline is designed to accomplish this task:

1. Value of information
   - agronomic information requirements
2. Historical perspective
   - methods of obtaining and reporting information related to agronomic resources
3. Data acquisition for agronomic surveys
   - ground, aircraft, satellites
4. Data handling and analysis
   - visual and numerical analysis

5. Surveying and monitoring agronomic resources
   - cultivated crops
   - rangelands
   - land resources
   - water resources
6. Agricultural systems of the world
7. Global agricultural information systems
   - digital data bases
   - geographic information systems (GIS)

Rationale. This course has a rather different orientation from most courses in remote sensing education. Rather than attempt to achieve some level of proficiency in the analysis and interpretation of remotely sensed images or data, the student will be exposed to the current and potential applications of the technology for improving agronomic resource information. It is hoped that upon completion of the course the student will have a solid grasp of the state-of-the-science in remote sensing and information technology as these relate to the delivery of accurate, useful and timely information about agronomic resources.

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REMOTE SENSING PROGRAMS AND COURSES IN ENGINEERING AND WATER RESOURCES

by

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Introduction

A recent survey [1] shows that there are more than 650 university-level courses dealing with remote sensing and image interpretation in the United States and Canada, including 130 courses taught in engineering departments (principally civil engineering). This paper describes the content of typical basic and advanced remote sensing and image interpretation courses and outlines typical remote sensing graduate programs of study in civil engineering and in interdisciplinary environmental remote sensing and water resources management programs.

Remote Sensing Courses

A basic remote sensing course taught in a 15 week, 45 period semester, should include the components shown in Table I. Such a course can serve as both a basic "survey of remote sensing" and also as the fundamental course upon which more specialized advanced remote sensing and image interpretation courses can build. Although the length of time spent on each topic, as well as the specific material covered under each topic, will vary from discipline to discipline, the general coverage of topics will be similar. Courses taught to engineering students will typically emphasize fundamental physical principles and the radiometric and geometric characteristics of various sensing systems, whereas courses taught to students from various disciplines which utilize remote sensing technology (e.g., botany, geography, landscape architecture, soil science) will typically emphasize remote sensing applications.

Advanced remote sensing/photo interpretation courses deal with specialized aspects of remote sensing image interpretation, both visual and quantitative, and with the characteristics and use of various forms of remote sensing/image analysis equipment.

Visual image interpretation courses deal with a variety of subjects, including: geologic and soil mapping; land use/land cover mapping; vegetation mapping; wetland mapping; agricultural applications; archeological applications; forestry applications; urban and regional planning applications; water resources applications; wildlife ecology applications; and applications to environmental impact assessment. In these courses, the emphasis is on the use of basic stereoscopic viewing equipment and visual image interpretation. These courses provide instruction and experience in following a systematic approach to the study of images for interpretive purposes. In many cases, visual image interpretation courses deal only with photographic interpretation. However, visual image interpretation techniques are also appropriate for the interpretation of satellite images, radar images, and thermal images.

Quantitative image interpretation courses deal with the use of remote sensing measurement instruments to extract numerical information from remote sensing data. Examples of information extraction would be the use of a densitometer to obtain film density measurements at points on an aerial photograph and the use of a digital computer to process the data recorded on Landsat CCTs (Computer-Compatible Tapes). An example of quantitative image interpretation would be the multiband analysis of Landsat data for the purpose of automatically (in a digital computer) recognizing and classifying elements in the scene into one of several discrete land cover classes. The output of such a process would generally be some form of map, perhaps a color-coded scene with each color representing a different land cover type.

Remote Sensing Graduate Programs

Ideally, graduate programs with an emphasis on remote sensing and image interpretation should be built around a core of five courses: (1) a basic course in fundamentals of remote sensing upon which the more specialized advanced remote sensing courses can build; (2) a course dealing with visual image interpretation; (3) a course dealing with quantitative (computer-based) image interpretation; (4) a basic photogrammetry course; and, (5) a basic surveying course. These five courses will comprise up to one-half of the course work required for the M.S. degree. The nature of other course work and thesis requirements will vary greatly, depending on the department in which the degree is being awarded. Tables II, III, and IV show sample programs of study at the University of Wisconsin-Madison and illustrate the differing characteristics of the programs housed in different academic areas.

Table II shows a sample program of study for an M.S. degree in Civil Engineering. This program assumes that the student has completed courses in surveying, geometronics, and basic photogrammetry as an undergraduate. The course work outside the core courses emphasizes advanced photogrammetry and physics.

Table III shows a sample program of study for an M.S. degree in an interdisciplinary environmental remote sensing program. This program includes courses in remote sensing, environmental studies, interdisciplinary synthesis and analysis (practicum and seminars), and thesis.

Table IV shows a sample program of study for an M.S. degree in an interdisciplinary water resources management program with a 15-credit "area specialty" in remote sensing. This program includes courses in natural science and technology, water resource institutions and public decision-making processes, analytical and design tools, synthesis and integration (interdisciplinary workshop), and area specialty.

Reference

1. Dahlberg, Richard E., and John R. Jensen, "Status and Context of Remote Sensing Education in the United States," NASA Conference on Remote Sensing Education, May 18-22, 1981.

TABLE I

TYPICAL CONTENTS OF A
BASIC REMOTE SENSING COURSE

Topic	No. of Periods
Introduction	1
Concepts and foundations of remote sensing	3
Elements of photographic systems	7
Radiometric characteristics of airphotos	4
Introduction to airphoto interpretation	4
Photogrammetry	4
Aerial thermography	6
Multispectral scan./spectral pattern recog.	4
Microwave sensing (principally Radar)	3
Remote sensing from space (princ. Landsat)	5
Summary	1
Exams	3
	45

TABLE II

SAMPLE PROGRAM OF GRADUATE STUDY

M.S. Degree in Civil Engineering
with a specialization in remote sensing

Course Title	No. of Credits
Fundamentals of Remote Sensing	3
Airphoto Interp. for Terrain Eval.	3
Remote Sensing Image Interpretation	3
Photographic Processing	3
Advanced Photogrammetry	3
Stereoplotters	3
Electromagnetic Fields (Physics)	3
Wave Mech. and Optics (Physics)	3
Surveying/Photogrammetry Seminar	2
Environmental Monitoring Seminar	1
Adv. Independent Study	3
	30

TABLE III

SAMPLE PROGRAM OF GRADUATE STUDY

M.S. Degree in Environmental Remote Sensing

Course Title	No. of Credits
Remote Sensing of the Environment	3
Airphoto Interp. for Terrain Eval.	3
Remote Sensing Image Interpretation	3
Basic Photogrammetry	3
Surveying	3
Environmental Ethics	3
Ecological Dimensions of Env. Impact	3
Environmental Monitoring Seminar	2
Environmental Monitoring Practicum	6
Thesis	6
	35

TABLE IV

SAMPLE PROGRAM OF GRADUATE STUDY

M.S. Degree in Water Resources Management
with an area speciality in remote sensing

Course Title	No. of Credits
Hydrology	3
Water Resources Engineering	3
Hydrogeology	3
Environmental Economics	3
Analysis of Environmental Impact	3
Water Rights Law	3
Statistics	3
Modeling & Analysis of Env. Systems	3
Water Resources Management Workshop	6
Remote Sensing of the Environment	3
Airphoto Interp. for Terrain Eval.	3
Remote Sensing Image Interpretation	3
Basic Photogrammetry	3
Surveying	3
	45

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The Quantitative Methodology of Remote Sensing: An Educator's Perspective

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Since the launch of Landsat-1 in 1972, computerized analysis of digital remote sensing data has become an increasingly attractive means of obtaining information about earth resources and the environment. A firm grounding in the mathematical and statistical foundations of this quantitative methodology is absolutely necessary to make effective use of it:

- To select the most appropriate methods for a given application;
- To avoid unsuspected pitfalls in the process which could invalidate the results of the data analysis process;
- To adequately evaluate the results obtained;
- To portray the results to others in an accurate and credible manner.

This paper explores the challenge of teaching the fundamentals of quantitative remote sensing to students from diverse disciplines and with a broad range of mathematical backgrounds. Because the concepts are fairly abstract and complex, the successful educator must take care to motivate and assist the students in mastering the concepts. He/she will strive to communicate intuitive notions of the concepts couched in settings as familiar as possible and use these settings to illustrate each mathematical or statistical formulation which is introduced.

The following incident, which actually happened, illustrates the importance of understanding the fundamentals of the quantitative methodology. A well-respected colleague in remote sensing research and education committed a gaff recently which had rather dire consequences. Faced with the task of economically performing large-area classification of multispectral remote sensing data, he used a principal components transformation to reduce the number of features to be used for the classification. However, to determine precisely which features should be used, he then applied a feature selection algorithm to the <u>combined</u> set of principal components <u>and</u> the sensor channels from which they were derived. He either forgot or was unaware that applying the algorithm to such interdependent features would result in ill-conditioned calculations and, at best, unreliable results. This fact was later called to his attention by a reviewer of his paper concerning the now-completed study. "Back to the drawing board!" as we say.

Remote sensing is an inherently multidisciplinary technology, a fact which must be recognized, accepted and dealt with in teaching as well as in developing and applying the technology. We cannot afford to overlook the fundamental principles involved in the phenomena we are exploiting and the tools we are applying, be they the devices used to collect the remote sensing data, the methods used to extract information from the data once collected, or whatever. To do so is to handicap our students, at best leaving them unable to take full advantage of the information available through quantitative remote sensing; at worst making them vulnerable to costly errors in misuse of the methods available, such as portrayed in the incident described above.

Given the broadly multidisciplinary character of the technology, what are some of the instructional strategies we can employ to communicate it most effectively to our students? I suggest we can categorize these strategies as contributing to: motivation, communication, reinforcement, and testing (the last to ensure the adequacy of the first three).

Strategy #1: Let the experts tell it. In some of the relevant areas, the course instructor will qualify as the expert and will be able to communicate with the authority, enthusiasm, and insightful presentation required to effectively transplant the roots of knowledge into fertile minds. In those subject matter areas where the instructor is not so qualified, he or she may bring an expert to the classroom, if not live then through videotapes or other multimedia materials which are becoming increasingly available.

Strategy #2: Use familiar non-remote-sensing illustrations of difficult concepts. Embedded in the remote sensing framework, the physics, mathematics, computer science, etc., become obscured by the interrelated complexities involved. My favorite example is the multivariate statistical methods used to perform classification of remote sensing data. Despite the mathematical complexities which result from having to deal with high-dimensional measurement spaces in remote sensing, the fundamental ideas and methods of multivariate statistical decision theory can be communicated effectively and efficiently through studying a pair of dice... or, better, two pairs of "funny dice." *

Strategy #3: Use laboratory-type experiences to reinforce the fundamentals. This is possible in every discipline area related to remote sensing, although the nature of the lab may vary greatly from one area to another. For teaching quantitative analysis methods, I have been involved with "hands-on" computer exercises in which the students actually perform classification of remote sensing data on available computer facilities. If this approach is infeasible due to cost or unavailability of the computer support, an alternative is an analysis workshop in which analysis by computer is simulated, supported by ground truth maps and actual computer printouts. Genuine understanding of the fundamentals sometimes comes only with an actual encounter with the technology, the "real world" application of these fundamentals.

The final "strategy" I will mention here should really not even need mention. To wit: The instructor must have a solid grounding in the fundamentals he or she is trying to teach. Now, it is no easier for a computer scientist or an electrical engineer to learn, say, the physics of geology than it is for an agronomist to learn the principles of digital image processing. But it can be done and it is done regularly in the multidisciplinary research and education programs which have grown up with the technology. An apprenticeship with such a program is probably the most effective way to prepare oneself to be an effective educator in the field of modern remote sensing technology and its applications.

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* See, for example, pp. 146-148, 159-161 in P.H. Swain and S.M. Davis, eds., Remote Sensing: The Quantitative Approach, McGraw-Hill, New York, 1978.

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REMOTE SENSING TRAINING NEEDS IN PROFESSIONAL FOREST AND RANGE RESOURCE MANAGEMENT CURRICULA

Merle P. Meyer[1/]

Recently, during a planning meeting in Washington, D.C. of a major federal agency involved in the development of applications of remote sensing to agricultural and natural resources management at the national level, a startling pronouncement was made by one of the participants. In essence, the statement was to the effect that any college level course in remote sensing which concerned itself totally, or primarily, with aerial photography and human photo interpretation did not deserve the title "Remote Sensing". This viewpoint was (is) symptomatic of one of two major problems currently inherent in remote sensing education where the professional forest and/or rangeland manager is concerned: (a) the apparent, and increasing, tendency for some remote sensing educators and research scientists to "purify" the remote sensing subject matter field by purging it of what they perceive as being mundane, vocational and applied -- i.e., aerial photography and aerial photo interpretation; and (b) the increasing dearth of educational institutions which provide the professional forest and range management student with the type and level of remote sensing training essential to his/her needs in the job market. In this regard, one must bear in mind that the majority of these graduates will, now and in the foreseeable future, work initially in field level positions for such agencies as the Bureau of Land Management, Fish and Wildlife Service, Forest Service, Soil Conservation Service, various state and county land and resource management units and private sector resource management organizations in forestry, agriculture, mining, ranching,

[1/] Professor, College of Forestry, University of Minnesota, St. Paul.

consulting, etc. In these job situations, and with rare exception, aerial photography in the hands of a properly trained resource specialist has no peer in the remote sensing technique arsenal in terms of cost-effectiveness and job utility!

In view of the increasing concern over this situation at the user level in the forestry profession, the Society of American Foresters Remote Sensing and Photogrammetry Working Group recently conducted a survey of the status of remote sensing training in the 43 accredited U.S. forestry schools. The results of this survey[2/], quoted in part below, are not encouraging:

> "The forestry profession in Canada and the United States was first among the renewable-resource specializations to recognize the utility of aerial photography and incorporate it into the day-to-day operations. This advance resulted largely from the development of the art and science of photo interpretation during World War II and its subsequent adaptation by foresters trained in its uses. Its utility was also recognized by the accredited forestry schools, many of whom incorporated it into their curricula in the late 1940's and early 1950's. By 1960, most schools were providing photo interpretation training for their students.
>
> Because of the universal acceptance of the necessity of air photo use at the field level, most employers have assumed that suitable training was being provided by the forestry schools. During the past several years, however, it has become apparent that students from some accredited U.S. forestry schools are entering the job market without adequate (or without any) training in aerial photo interpretation. SAF's Remote Sensing and Photogrammetry Working Group has received complaints in this regard from three sources: (a) forestry school faculty members, (b) recent graduates, and (c) employers of recent graduates. One employer pointed up an associated problem in that a recent graduate (employee) presented evidence of something called "remote sensing" on his grade transcript, but had no knowledge of how to handle, or properly utilize, aerial photographs.
>
> As a consequence, the working group in 1979 submitted a questionnaire to all of the 43 accredited U.S. forestry schools. Some assumptions were necessarily made in framing the questionnaire: (a) that the courses being taught, even though they might be titled "remote sensing", primarily involved (as they should) training in aerial photo interpretation; (b) that the equivalent of two quarter credits which include some laboratory exercises, are necessary at a minimum. Upon completion of the survey tabulation, each

[2/] Meyer, M., R. Harding and J. Ulliman. 1981. Status of airphoto interpretation training in accredited U.S. forestry schools. (In press for publication in June, 1981 issue of Journal of Forestry).

respondent received a copy for review.

> In summary, of the 43 accredited schools, 30 require a course in aerial photo interpretation. Of these, 25 provide in excess of two quarter credits of work; five provide less than the two quarter credit minimum. Eleven schools do not require training but recommend an elective course or courses which are taken by more than 50 percent of the students in five schools, but by less than 50 percent in the other six schools. Two schools neither require training nor recommend that electives in remote sensing (aerial photo interpretation) be taken.
>
> The working group finds the results of this survey disturbing in that fewer than 60 percent of the accredited schools require adequate (in our view) training in aerial photo interpretation for their graduates. This deficiency can, we feel, prove a serious handicap to the beginning professional forester. Very often many of the tasks first assigned to the beginner involve intensive (frequent) use of aerial photographs (e.g., forest and range inventory, timber harvest planning, plantation surveys). Lack of competence in this work places the burden of training upon the employer and may adversely affect the new employee's future job status.
>
> In conclusion, it is our feeling that the situation is sufficiently serious to warrant the attention of SAF's Education Policies Committee. Consideration should be given to assuring that the forestry student will receive adequate training in this essential skill...".

Although the remote sensing training situation in U.S. forestry schools is unsatisfactory, its condition is considerably healthier than what exists in U.S. range management schools. Few of the latter require remote sensing training for their students, sometimes because of its unavailability - in other cases, because they are unaware of its utility. As in forestry, a number of employers have indicated dissatisfaction with the situation since this lack of training at the professional school limits entering employee capability and necessitates expensive on-the-job training. The employers rightly contend this function should be the province of the schools. Probably the best way to induce the schools to accept this responsibility will be through exertion of pressure by the user groups - in particular, by way of their professional societies (e.g., Society of American Foresters, Society for Range Management).

The job does not end, however, with the institution of remote sensing in the professional schools' forestry and range curricula. It must also be of a type and content which is of the greatest possible utility to the student entering the job market. This places the responsibility upon the remote sensing instructor to become suitably informed as to what the specific needs are. Unfortunately, however, it would appear some remote sensing instructors involved in these professional resource management areas are not always doing their homework!

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The Requirements of Teaching an Interdisciplinary Technology From the Geographic Perspective

by

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Introduction

In order to appreciate the difficulties in designing a remote sensing course or course sequence from a geographic discipline perspective it is important to note the all encompassing nature of Geography. There are many scholarly definitions of Geography ranging from: The study of spatial interactions; through the study of man's relationship to the land; to the systematic study of regional and global distributions. At a primary level, the field of Geography is often split between those geographers who deal with the physical environment and those involved with the study of cultures. Discussion of the subareas of the Discipline of Geography could go on and on, but it suffices to say here that geographers today find themselves dealing with both fundamental and applied research issues with important implications for teaching which cross a broad spectrum of disciplinary boundaries. We find Geographers doing research in areas which touch on Agriculture, Forestry Range, Geology, Hydrology, Sociology, Economics; the list could go on and on. The material which follows, details the growth of the remote sensing course offerings within Geography and concludes with some thoughts on the impacts which remote sensing can, and is having on Geography.

Remote Sensing Course Offerings in Geography

H.V.B. Kline, Jr., writing on the prospects for air-photo interpretation in American Geography Inventory and Prospect (in James and Jones, 1954), quotes John E. Kesseli as saying, "Only in departments so sufficiently staffed to consider all parts of the geographic field, can it be expected that air photography has found or may find, its due consideration as a research field." Furthermore, the student "...is inclined to neglect field and laboratory courses which provide a training in the gathering and interpretation of information, hoping that his problem will take care of itself when the time for independent research arrives." It is hoped, in geography this situation is changing.

By 1950, some 13 geography departments, all east of the Mississippi River, offered courses in aerial photographic interpretation. In 1960, the number had grown to 25 courses, with schools on the West Coast and in Colorado and Utah offering courses. The 1961 distribution of states where courses were taught can be characterized as 3 nodes: a West Coast and Central Mountain State node; an Upper Great Lakes node; and a Central East and Gulf Coast node. In the early 1960's, the expansion of course offerings in geography accelerated coincident with the introduction of the term "remote sensing" and an increased interest within the federal government in aerial reconnaissance as a means of obtaining environmental information. By 1971-72 (based on information from Schwendeman, Jr., 1972; and Eitel, 1972; and responses to questionaires distributed to Geography departments throughout the nation), Estes and Thaman (1974) found that 99 institutions in 37 states and the District of Columbia offered courses in either remote sensing or aerial photographic interpretation. The pattern expressed by the 1971-72 distribution is one of intrastate expansion and filling in between the three nodal areas expressed in the 1960-61 distribution. Of the 99 institutions in 37 states, some 74 institutions in 35 states offered graduate programs in geography. Thus, in little more than a decade, there was an increase of almost 300% in the institutions offering courses and a gain of slightly over 100% in the number of states where these courses were offered. Furthermore, there was also a 300% gain in offerings at schools with undergraduate programs, along with a 120% gain in states with graduate programs.

In 1975-76, the total number of departments offering courses in remote sensing and/or air-photo interpretation was 165. These 165 departments are in 44 of the 50 states (Schwendeman, Sr. and Schwendeman, Jr., 1976). At this time, the only states where, to the best of my knowledge, departments of geography do not currently offer either remote sensing or photo interpretation are Alaska, Arkansas, Maine, Missouri, Rhode Island, and West Virginia. Thus, since 1971-72 there has been continued expansion in the number of institutions offering remote sensing/air-photo interpretation (a 40% increase over the 1971-72 figures). A recent article by Nealey (1977), based on responses to questionaires mailed to institutions across the country, lists a total of 103 courses taught in geography departments in remote sensing and related topics. This total represents 22% of a nationwide total of 470 courses in all disciplines identified in his study. Even if we accept the inconsistency between Nealey's and our data to be equal for all disciplines (Nealey's 103 courses to our 165), geography's role in remote sensing instruction is still significant. *Geography teaches more air-photo interpretation and remote sensing courses than any other discipline in the country.*

At the 1964 conference sponsored by the National Academy of Science/ National Research Council, (National Academy of Science National Research Council, 1966) Peter Gosling described an "air of enthusiasm which inspired panel members to work eagerly and imaginatively on their respective reports." This meeting brought together at a critical early stage in the United States space program the talents of a number of distinguished geographers to make recommendations on the potential of the newly developing field of spacecraft remote sensing as a tool for the geographer. Statements at this meeting such as: "The opportunity to obtain synoptic, regularly repeated views of the whole earth and the changing surface of the lands and seas will have a profound effect on the growth and internationalization of geographic sciences," illustrate the potentials recognized by these leaders in the field (National Academy of Science National Research Council, 1966). It is a pity that more of the attendees did not maintain their enthusiasm!

The exploitation of the improved or unique information available to the geographer via the application of remote sensing techniques has barely begun. Yet, when thoughtfully analyzed, it can be seen to provide the geographer with significant improvements in the quantity, quality, and timeliness of data required. As more geographers become aware of the significant implications of remote sensing for providing such data, the true impact of this technique in the discipline will be felt. Remote sensing, like cartography, is approaching such a state of technology and body of coherent knowledge and theory that it can almost be viewed as a discipline in and of itself. As an illustration of this point, when I started teaching at the University of California, Santa Barbara (UCSB) in 1970, there was one course "on the books", Aerial Photographic Interpretation. This course offering was expanded that year to a one quarter air-photo and one quarter remote sensing offering. By 1975, just after Dr. David Simonett arrived at UCSB, our course offerings expanded to a three quarter sequence. Again, our basic one quarter air-photo course; a one quarter course which stressed image processing as taught through analysis of Landsat data; and a one quarter course on "unconventional imaging systems".

Today at Santa Barbara, we teach the following courses, descriptions of which are taken directly from our University course catalog:

Undergraduate Level:

115A Geographic Photo Interpretation (4) Estes, Prerequisites: Geography 3 or consent of instructor. Introductory Botany and Geology recommended. Lecture 2 hrs. Lab 4 hrs. Interpretation of physical and cultural geographic phenomena as recorded by orbital and aerial sensing systems with emphasis on conventional aerial photography.

115B Geographic Remote Sensing Techniques (4) Estes, Simonett, Prerequisites: Geography 115A or equivalent, and consent of instructor. Lecture 2 hrs. Lab 4 hrs. Human and computer interpretation of environmental phenomena recorded by orbital & aerial multispectral sensing systems. Emphasis is on the nature of the data recorded and the extraction of useful decision information. Contemporary Landsat data is used. Lab uses an interactive image analysis program.

115C Intermediate Geographic Remote Sensing Techniques (4) Estes, Simonett, Prerequisites: Geography 115B or consent of instructor. Lecture 2 hrs. Lab 3 hrs. Intermediate instruction in the interpretation of environmental phenomena recorded by aerial and satellite platforms with emphasis upon microwave and infrared regions.

135 Thermal Infrared Remote Sensing (4) Staff, Prerequisites: Geography 115B or consent of instructor, Lecture 3 hrs. Theory and applications of thermal infrared remote sensing. Contact and remote measure-

ments of energy exchanges at the earth's surface. Analysis of thermal imagery and application to microclimate, soils and energy conservation.

Graduate Level:

214 Microwave Remote Sensing (4) Estes, Simonett, Prerequisites: Geography 115C or consent of instructor. Seminar, 3 hrs. Examination of active and passive microwave sensing. Ground spectrometer, aircraft systems, space systems, Radiometry, scattering theory, practical applications and problems.

215 Seminar in Remote Sensing (2-4) Estes, Simonett, Prerequisites: Geography 115B or consent of instructor. It is recommended that Geography 214 precede Geography 215. Advanced concepts in multispectral, multitemporal, manual, automated and hybrid remote sensing techniques. May be repeated more than once with changes in content, methods and applications areas examined.

216 Remote Sensing Instrumentation and Software (4) Simonett, Prerequisites: Geo. 115B, 125, and 173/173L, or consent of instructor. Seminar, 3 hrs.

235 Thermal Infrared Remote Sensing (4) Staff, Prerequisites: Geog. 115B or consent of instructor. Recitation, 3 hrs, Seminar 1 hr. Theory and applications of thermal infrared remote sensing. Contact and remote measurements of energy exchanges at the earth's surface. Analysis of thermal imagery and application to microclimate, soils, and energy conservation. Seminar on topics of individual student research and reading.

As the reader can see, we now offer eight quarter courses on remote sensing related topics in Geography at UCSB. Indeed, as different instructors teach our 215 Seminar, students are encouraged to take the course more than once for credit. As such, it is not unusual for a student to have more than one 215 seminar on his/her record. Many of our students take 6 or 7 remote sensing classes and a few have taken all we offer. This totals 36 quarter units and still we feel that more offerings may be appropriate, particularly course dealing with the fundamentals of Geographic Information Systems (GIS) and the linkages between Remote Sensing, GIS's. This area must be integrated in future remote sensing geography cirricula.

The quantative revolution of the late fifties and sixties in geography taught geographers to be more rigorous in our approach to data analysis. The remote sensing revolution is now showing a growing number of geographers that we can be more rigorous in our methods of data collection. This is particularly true with respect to the collection of data on spatially distributed phenomena. By combining advanced data collection procedures including remote sensing with the potentials inherent in advanced geographic information systems to facilitate and improve the rigor of our data analysis techniques and employing this synergism to the modeling of spatially distributed biophysical and socioeconomic phenomena the true potential of geographical analysis comes closer to realization. Yet, just as the acceptance of the quantitative mathematical school of geographical analysis was slow in coming and severely criticized by the "old guard", so too, is remote sensing feeling this same type of restraint as we attempt to awaken geographers to its capabilities.

Conclusion

Remote sensing is a reality within geography whose time has come. It is too powerful a tool to be ignored in terms of both its information potential and the logic implicit in the reasoning process employed to analyze the data. When allied with the traditional cornerstone of geography, i.e., cartography, in its new digital raiment, the two techniques can go far beyond being mere technologies. We predict they could change our perceptions, our methods of data analysis, our models and our paradigms. This process to some extent has already begun on the physical/environmental side of the discipline but the full potential for cross-fertilizing synergism which can enrich the whole field of geography will be realized only if a larger share of the regional, economic, and social geographers make some use of the technique, and only if geographers aggressively seek the research funding required to demonstrate the magnitude of the promise held in remote sensing in these areas. Finally, what is required to increase the impact of remote sensing in geography is a concerted effort on the part of geographer and others who specialize in remote sensing to conduct their research thoughtfully so as to more effectively impact their disciplines.

Acknowledgement: The author acknowledges that portions of this text are taken essentially verbatim from an article by himself, John Jensen, Dept. of Geography, University of Georgia, and David Simonett, Dept. of Geography, UCSB, entitled, "Impacts of Remote Sensing on U.S. Geography", which appeared in Remote Sensing of Environment, Volume 10, pp 43-80, 1980.

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CORSE-81

The 1981 Conference On Remote Sensing Education
May 18-22, 1981 Session No. 2

GEOLOGICAL APPLICATIONS AND TRAINING IN REMOTE SENSING

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This paper summarizes some of the experiences, methods, and opinions developed during 15 years of teaching an introductory course in remote sensing at several universities in the Southern California area. Although the course is offered in Geology Departments, every class includes significant numbers of students from other disciplines including geography, computer science, biology, and environmental science. The instructor or teaching assistant provides a few hours of tutorial lectures (outside of regular class time) on basic geology for these nongeologists. This approach is successful because the grade distribution for nongeologists is similar to that for geologists. The schedule for a typical one-semester course is given in Table 1. To condense this schedule for a one-quarter course, some lectures are combined, one field trip is eliminated, and some of the interpretation projects are eliminated. The text is Sabins (1978) and the interpretation projects are from printed class handouts that have evolved into a laboratory manual (Sabins, 1981).

As shown in the schedule (Table 1), the first half of the course is devoted to the basic remote sensing systems and images: aerial and satellite photography, Landsat, thermal infrared imagery, radar imagery, and digital image processing. The second half of the course emphasizes the application of these systems to resource exploration, environment and land-use, and natural hazards. Throughout the course, the objective is to train students in:

1. Physical principles involved in remote sensing.

2. Sensor technology, including geometric distortion and defects of images.

3. Applications of remote sensing.

4. Interpretation of images.

5. Correlate image interpretations with field geology.

The course is taught during a single three-hour session each week which facilitates a combination of quiz, lecture, and image interpretation. At the beginning of each class there is a 15-minute quiz on the reading assignment which serves two purposes: (1) students are encouraged to prepare for each class; (2) because the students are prepared, the lecture does not need to repeat material in the reading assignment.

The lecture for each class is organized around projection slides of images and maps that complement the reading assignment. Supplemental handouts and lectures describe the newer remote sensing systems (Landsat 3, HCMM, Seasat) for which images have only recently become available.

A major portion of the class (50 percent of grade) consists of individual student projects to interpret images. As shown in Table 1, the projects are correlated with the lectures and reading assignments. The projects provide "hands-on" experience in making basic calculations and interpreting typical images. After each project is graded and returned to the students, the instructor reviews and discusses his interpretation with the class. Figure 1 is a typical project to interpret and compare an aerial photograph and a thermal infrared image. The students interpret the fault and fracture patterns that are preferentially expressed on the infrared image and select localities for drilling water wells where maximum fracture intersections occur. The student report calls for an explanation of the signature of fractures and for a comparison of the two images.

The class participates in two weekend field trips to localities that are covered by images of the interpretation projects. The trips are scheduled after the interpretation projects are completed, graded, and returned to the students who can then check their interpretations in the field. Field trip topics include active faults, cinder cones and lava flows, lineaments, thermal inertia estimation, Seasat radar interpretation, mapping geologic structure on thermal infrared images. The field trips effectively relate the classroom work to the "real world".

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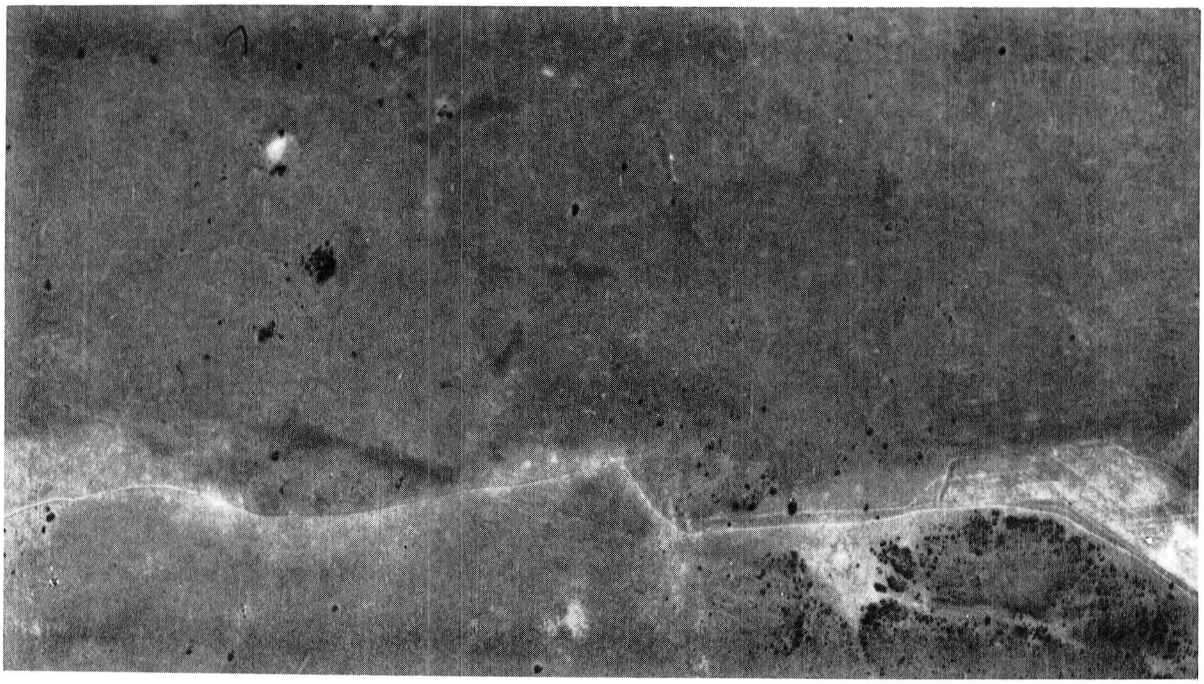
EARTH SCIENCE 410 "REMOTE SENSING", CSU FULLERTON, FALL SEMESTER, 1980 - F. F. SABINS

Class	Lecture Topic	Interpretation Project (Date Due)	Read for Next Class*
Sept. 2	Course overview Stereo photography	Stereo vision test (Sept. 2) Fundamental considerations (Sept. 9) Aerial photography calculation (Sept. 9)	Chap. 1 Chap. 2 Chap. 3
Sept. 9	Fundamental considerations Aerial photography Manned satellite imagery	Goose Egg Structure (Sept. 16) Ordering aerial photographs (Sep. 16)	Chap. 4
Sept. 16	Landsat	Ordering Landsat Images (Sept. 30) Virginia, Kentucky, W. Virginia (Sept. 30) Zagros Mountains, Iran (Oct. 7)	"Landsat 3"
Sept. 23	No class	----	---
Sept. 30	Landsat (cont'd)	Stereo Landsat, Pakistan (Oct. 7)	Chap. 5 and "HCMM Satellite"
Oct. 7	Thermal IR	Thermal IR calculations (Oct. 21) Thermal inertia estimates (Oct. 21) Thermal IR S. Africa (Oct. 21)	Chap. 6 and "Seasat Radar"
Oct. 14	No class	----	---
Oct. 21	Radar	Radar calculations (Oct. 28) Death Valley interpretation (Oct. 28) Mojave Desert mosaic (Oct. 28)	Chap. 7
Oct. 28	Digital image processing Field Trip Briefing	Interpret field trip images (Nov. 1) Digital calculations (Nov. 4)	---
Nov. 1,2	Field trip	Coachella and Imperial Valleys	---
Nov. 4	Digital Image Processing	Landsat Ratio Images (Nov. 11)	Chap. 8
Nov. 11	Resource exploration	Wildcat well, Little Dome, Wyo. (Nov. 25)	Chap. 11
Nov. 18	Field trip briefing	Lineament Interpretation, Granite Mountains, CA (Nov. 22)	Chap. 9
Nov. 22,23	Field trip	Mojave Desert	---
Nov. 25	Environment and land use	Bathymetry interpretation (Dec. 2) Movement of sea ice (Dec. 2) Map sea ice on radar & thermal IR (Dec. 2)	Chap. 10
Dec. 2	Natural hazards	Recognition of active faults (Dec. 9) Landsat images of flooding (Dec. 9)	Chap. 12
Dec. 9	Course review; New Technology	----	---
Dec. 16	Final examination	----	---

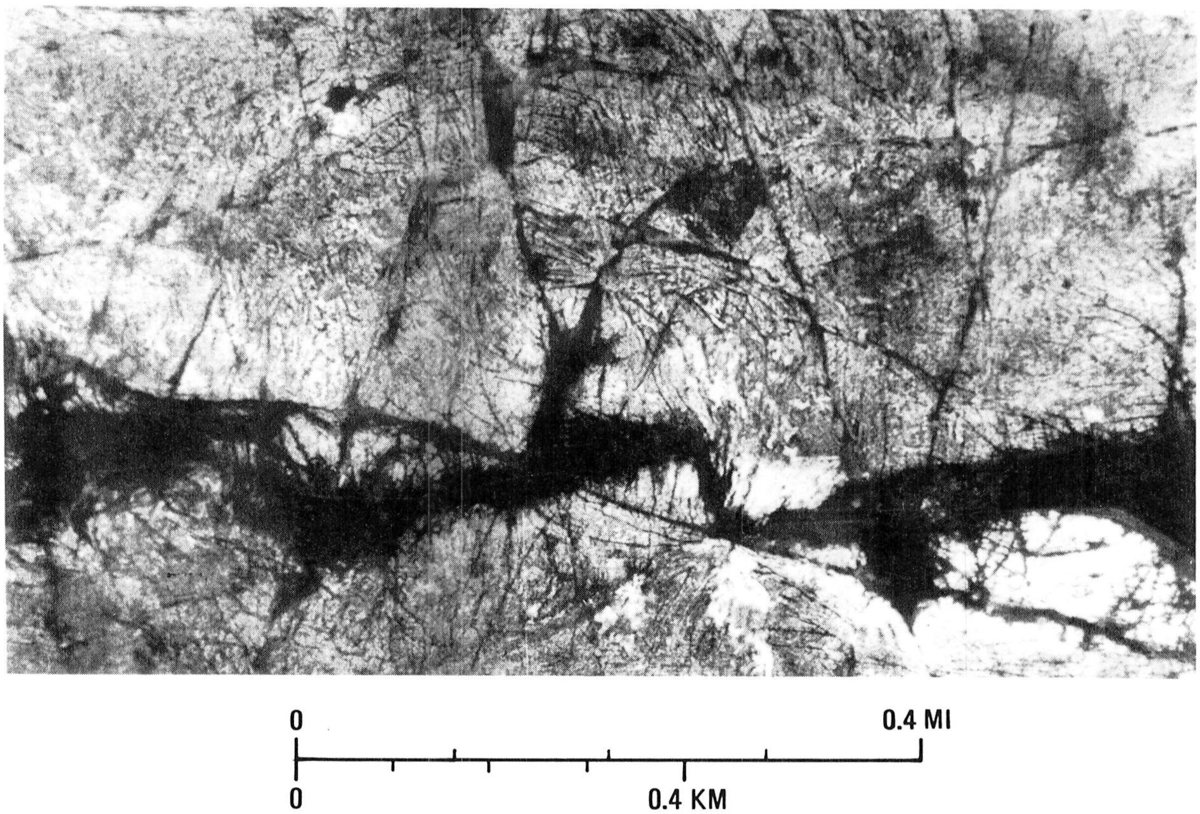
* From assigned text "Remote Sensing - Principles and Interpretation" by Sabins (1978) and supplemental handouts.

GRADING FACTORS

Reading examinations (Drop single lowest grade before averaging; no makeups)	30%
Interpretation projects - weighted according to difficulty (Drop single lowest grade before averaging) (5-point penalty for each day late)	50%
Final examination	20%
	100%



A. AERIAL PHOTOGRAPH



B. NIGHTTIME THERMAL IR IMAGE (8 to 14 μm)

FIGURE 1

INTERPRETATION PROJECT TO COMPARE IR IMAGE AND AERIAL PHOTOGRAPH—SOUTH AFRICA. FROM SABINS (1981, FIGURE 8.5)

Session 2-B Discussion Notes:

A member of the audience asked Dr. Kiefer if graduates of the remote sensing program at Wisconsin were able to find jobs. He responded by noting that students come to the program with a strong discipline background by virtue of their undergraduate degree. (See papers and discussion notes in Session 1-B.)

A question was asked concerning how one gets the administration of an educational institution to accept the idea of a new interdisciplinary degree area. Dr. Kiefer pointed out that at Wisconsin the Institute for Environmental Studies reports directly to the chancellor of the University. Reference was also made to Dean Walton's paper in Session 1-A.

A comment from the audience was made to the effect that laboratory exercises are very important.

There was some discussion (not without controversy) that at some point in time there would be a need for remote sensing technologists. The point was made that this need is more likely to occur in situations where there is enough remote sensing activity to warrant a team approach to problems.

Questions were raised as to how to relate remote sensing and computer science. At the student level, Phil Swain commented, the EE577 course does the job at Purdue. At the faculty level, the University of British Columbia has solved the problem by means of a Forestry/Computer Science joint appointment.

As the session drew to a close the following comments were made: the methodology of remote sensing would interface nicely to a general education program; we need to get elements of remote sensing into high schools; an undergraduate student made the comment that he perceived the need for 2 and 4 year programs in remote sensing; the demands for remote sensing technologists are there.

Session 3

Poster Session

During the Poster Session, twelve presentations were made. Written summaries follow for all presentations except those which duplicated presentations in other sessions. Papers are arranged in alphabetical order by author. The chairman of the poster session was Douglas Morrison, Purdue University.

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May 18-22, 1981 Session No. 3

Some Characteristics and Advantages of Landsat 3 Return Beam Vidicon Images

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The highly successful multispectral scanners (MSS) on board Landsats 1, 2, and 3 have diverted attention from the fact that other sensors were also aboard. Landsats 1 and 2 had high resolution return beam vidicon (RBV) television camera systems which were designed to cover the same area of view in three spectral bands. Band 1 covered the blue-green from 0.475 to 0.575 micrometers; band 2 covered the orange-red from 0.580 to 0.680 micrometers; and band 3 covered the red-near infrared from 0.690 to 0.830 micrometers. In both Landsats 1 and 2 the RBV systems did not function as expected and full attention went instead to the MSS output.

A different RBV system is on board Landsat 3. There are two identical cameras mounted side by side and each has the same wideband spectral response of 0.51 to 0.75 micrometers; from yellow into the near infrared. Each one covers a square area of slightly more than 61 miles (99 km.) on a side. Taking sidelap into account, the overall width covered by two adjoining images is about 114 miles (183 km.). Successive adjoining RBV scene pairs correspond in area to single frames of MSS images produced on Landsat 3. Thus, a single RBV image is approximately the equivalent of ¼ of the area of an MSS image.

In spite of the fact that there have been some processing problems associated with the production of Landsat 3 RBV scenes, a large number are presently available. It may not be possible to obtain repeated coverage of a given area the same way we have been accustomed to receiving MSS information. However, there appears to be adequate coverage of the United States and other parts of the world and the special characteristics of these images make them worth examining.

One important advantage of an RBV scene is the synoptic view it provides. A 1:500,000 paper print of the size 7.65" x 7.65" (19.4 cm. x 19.4 cm.) encompasses an area of about 3,721 square miles (9,637 sq. km.) and this compares very favorably in coverage to small scale aerial photography. For example, an aerial photograph at 1:80,000 in the standard 9" x 9" (23 cm. x 23 cm.) format covers an area of 129 square miles (334 sq. km.). The RBV image would, therefore, cover an area about 29 times larger than such a photograph.

At the latitudes of North Carolina a U.S. Geological Survey topographic quadrangle of the 7½ minute (1:24,000) series covers an area of about 60 square miles (155 sq. km.). An RBV scene of this same region is equivalent to the total areas of about 62 of these maps.

A second important advantage of Landsat 3 RBV images is that the ground resolution is 38 by 38 meters. Compared to the resolution of the MSS which is 79 by 79 meters the RBV provides us with a wealth of detail useful for many purposes. A great variety of man made structures are visible including bridges, roads, docks, and small airfield. Agricultural field patterns are clear and settlements of various sizes can be identified and delineated. In my opinion the RBV image is qualitatively closer to a small scale aerial photograph than it is to an MSS image.

A third advantage is related to the approximate panchromatic spectral response displayed in RBV images. There are many aerial photographic interpreters in the world utilizing their skills in a variety of professions and for a multitude of purposes. These people are accustomed to working with panchromatic photographs and they should have no difficulty understanding and putting RBV images immediately into use. An easily understood image requiring no special knowledge or equipment to be interpreted would seem to be a logical step on the way to using MSS products. Thus, the RBV image should have great appeal as an information souce about the surface of the earth to all those requiring such data who may only have a simple magnifier as a working tool. I believe that we will come to appreciate the RBV when more users are working with it and have a means of exchanging information about image utility and characteristics with others.

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The 1981 Conference On Remote Sensing Education
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REMOTE SENSING - PRESENT AND FUTURE

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[*1]Remote sensing, a term that has found its way extensively into the geographic and other spatially-oriented literature during the decade of the seventies, still gets the same reaction from many scholars that quantitative techniques received during the sixties. Uncertainties about the sophisticated technology and the contrast between the "pretty" picture and the digital computer-implemented analysis methods often leave people uncomfortable about applying this technique to their research. Remote sensing is not a brain child of the seventies. For over 100 years man has made attempts to ascend[*2] above the earth to learn[*3] more about its spatial arrangements. In order to record[*4] the so-called bird's eye view, various platforms have been used to mount cameras to take pictures[*5] from a distance above the earth, thus enabling scientists[*6] to add a new dimension to their research.[*7] Aerial photography has become the widely accepted term for this technology.

An outgrowth of the space sciences and technology has been the development of satellites[*8] carrying earth-observational sensor systems. This has resulted in the availability of enormous quantities of photographic and digital data above the earth with synoptical emphasis. Modern, high speed digital computers are well suited to reduce these data to useful information both quickly and economically. The synthesis of computer technology with the new observation systems has revolutionized our ability to obtain accurate and current information about our world.

Bodechtel and Gierloff-Emden have called remote sensing the third[*9] discovery of the earth. They refer to voyages of exploration and discovery of continents outside the Mediterranean realm as the first phase, while the second discovery second discovery alludes to the work of such scientific adventurers as Livingstone and von Humboldt who explored much of the interior of Central Africa and Middle and South America respectively. The second discovery was exclusively directed towards non-European territory and carried out primarily by Europeans. The third discovery of the earth has its beginning in the development of non-terrestrial recording techniques which has led to the LANDSAT system,[*10] the present workhorse among the non-terrestrial recording devices.

Before discussing any future systems, it might be best to explain the present LANDSAT system. The Nimbus type satellite, used to carry the platform[*11] for LANDSAT moves in an almost perfectly circular orbit at an altitude of about 917 km or 570 miles inclined at 81° relative to a plane passing through the earth's equator.[*12] This near polar orbit is also sun synchronous, crossing the equator on the day side of earth 14 times every day at approximately 9:30 a.m. local time in each transit. Each successive orbit shifts westward about 2875 km at the equator. On the following day the next 14 orbits follow those of the previous day, but each is offset westward by about 159 km or roughly 100 miles.[*13] Images obtained for any two adjacent orbits show about 15 percent sidelap at the equator; this sidelap increases to about 85 percent near the poles. All parts of a large region, such as a continent, are imaged during the succession of shifted orbits in a cycle lasting 18 days. Thus, in principle, any area may be imaged every 18 days, but, in practice, cloud cover usually reduces the coverage to some simple multiple of 18, which depends on geographic location and time of year. According to NASA, a typical case in the eastern United States is 54 days, but this varies with season.

The LANDSAT carry two imaging sensor systems. One, a television camera system referred to by the ever-present government acronym RBV[*14] for Return Beam Vidicon, has functioned properly only on LANDSAT 3. The second system is a[*15] multispectral scanner, also known as MSS, which produces continuous image strip built up from successive scan lines extended perpendicular to the forward direction of the satellite's orbital motion.[*16] Reflected light from the ground cover is transferred by an oscillating mirror in the MSS to a recording system after passing through filters that select different wave length intervals of this light. Each of the four wavelength channels processes a predetermined spectral interval or band (the MSS bands are numbered 4, 5, 6, 7, simply to avoid confusion with the three RBV bands, which are numbered 1, 2, 3). The choice of particular spectral bands is based on (a) accommodation to atmospheric windows and (b) character of target to be examined. One principal use of this multispectral capability stems from a basic property of materials. Because various classes of features found on the surface of the earth reflect differing[*17] amounts of light at different wavelengths or wavelength intervals, they can be separated and identified by their own characteristic reflectance patterns,[*18] or spectral "signatures." For example, vegetation typically reflects more green light than red and is very reflective in the infrared. Many dry soils, by contrast, do just the opposite.

The light reflectance data obtained by the MSS on board LANDSAT are first converted to electrical signals, which vary in proportion to the intensity measured in each band. These analog signals are then converted into digital form and[*19] transmitted to one of the receiving stations in the continental United States or foreign stations in participating countries.

The digital video data can be re-formatted into computer compatible tapes (also known as CCTs) and analyzed by investigators and users through a variety of programs designed for specific hardware. Alternatively, the digital data can be reconverted at ground processing facilities into sets of black and white photo images,[*20] one for each band, or color images can be made from combinations of individual black and white images by projecting each given band through a particular filter.[*21] The usual combination consists of band 4 (green) projected through a blue filter,[*22] and band 5 (red) projected through a green filter, and band 7 (near infrared) projected through a red filter. In this rendition, (called a false color image), which is comparable to the standard false color infrared product of conventional color infrared photographing growing vegetation will appear in various shades of red, rocks and soil will normally show color ranging from bluish through yellows and browns, water will stand out as blue to black depending on depth and amount of[*23] suspended sediment, and cultural features (cities and major roads) will usually be recognized by bluish - black tones arranged in characteristic patterns. These general identifying colors will vary somewhat depending on such intrinsic scene factors as angle of illumination because of time of year; vegetational differences due to seasonal variation, and atmospheric conditions, as well as on the processing and printing methods and materials used in a particular photo lab plus the degree of enhancement employed for a particular image.

Essentially, the above description is appropriate for the data obtained thus far through the LANDSAT program. The National Aeronautical and Space Administration has not been idle since the successes of the LANDSAT program. Instead continuous efforts have been made to guide the initial earth observation satellite system to meet the needs and desires of the scientific communities for the 1980s with a second generation of remote sensing systems.

It became apparent, with the successes of LANDSAT 1 and 2, that a more suitable and second generation space flown scanner system would provide superior remotely sensed data from vegetated targets. A satellite dedicated to and designed for vegetational monitoring is a new experimental earth resources satellite, scheduled for launch in late 1981 or early 1982. LANDSAT D,[*24] which will become LANDSAT 4 after it is successfully put into orbit,[*25] has two major distinctions from its three predecessors:[*26] First, a new multispectral scanner system called the thematic mapper, and secondly, the pixel size.[*27] The Thematic Mapper, known as the TM, is an object space scanner which bears a qualitative resemblance to the present MSS. In quantitative terms,[*28] however, the TM will be a far more sophisticated instrument than its predecessors. It will have finer resolution, seven bands with narrower and better defined spectral responses to maximize the information context for green vegetation, higher radiometric accuracy and resolution, more sophisticated inflight calibration techniques, and greater geometric fidelity.[*29]

The LANDSAT D spacecraft will be assembled around a Multimission Modular Spacecraft (MMS) bus. This standardized bus will have pointing accuracy and stability characteristics which are superior to those used until now and will minimize the needs for development of mission unique spacecraft support systems. LANDSAT D will be launched into a sun-synchronous circular orbit of 705 km altitude from which it will repeat cycle of 16 days. Its nominal equatorial crossing time will be 9:30 a.m.

LANDSAT D's altitude is lower than that of the first three LANDSATS. The significance of this lies in the fact that this will permits its future retrieval and refurbishment by the Space Shuttle Orbiter. The LANDSAT D mission will occur during the period of transition between the era of spacecraft which are launched by the Shuttle and which can either be retrieved or refurbished in space. Hence, the LANDSAT D satellite and its sensors must be compatible with both the old and new mode of operations.

The performance parameters for the Thematic Mapper are of notable significance to the scientific user community. The parameters have evolved from experience gained in the operation of the present MSS. The seven spectral bands selected for the Thematic Mapper are the result of extensive research with regard to design criteria of complexity, signal/noise ratios, detector response, energy needs, weight, reliability, data processing and storage considerations, atmospheric effects, etc. and comparison of various combinations of spectral regions. For example, the short wavelength band of the present MSS, whose spectral passband is 0.5 to 0.6 um, has been able to map underwater features to a far greater extend than was anticipated. Band 1 of the Thematic Mapper coincides with the maximum transmissivity of water and will therefore demonstrate coastal water mapping capabilities superior to those of the present MSS. It also has beneficial features for the differentiation of coniferous and deciduous vegetation. Bands 2-4 cover the spectral region which is most significant for the characterization of vegetation. Vegetation moisture may be estimated from Band 5 readings, and plant transpiration rates may be estimated from the thermal mappings in Band 5. Band 7 is primarily motivated by geologic application, including the identification of hydrothermally altered rocks. The band profiles, which are narrower than those of the present MSS, are specified with stringent tolerances, including steep slopes in spectral response and minimal out-of-band sensitivity. Specifically, the bands and their spectral range are designed for the following principal applications: Band 1 with its spectral range of 0.45 um to 0.52 um for coastal, soil/vegetation differentiation and deciduous/coniferous differentiation. Band 2, ranging from 0.52 um to 0.60 um emphasizes green reflectance of healthy vegetation. Band 3, in the 0.63 to 0.69 um range shows chlorophyl absorption for plant species differentiation. Band 4's 0.76 to 0.90 um range will be most beneficial in biomass surveys and water body deliniation. Band 5 will measure vegetation moisture and differentiate snow and cloud cover in the 1.55 to 1.75 um range. Band 6, ranging from 10.4 to 12.5 um, will detect plant heat stress and be used for other thermal mapping. Band 7, functioning in the 2.08 to 2.35 um range will be used for hydrothermal mapping. A comparison of satellite sensor bands for vegetation mapping concluded that the TM 1 through 4 were indeed well suited for remote sensing of vegetated targets and significant improvements can be expected from the Thematic Mapper over the MSS of LANDSATS 1, 2 and 3, resulting from optimal spectral resolution alone.

It is evident that the TM will render much more specific data for the researcher but perhaps equally important may be the fact that LANDSAT D will provide us with much finer resolution than its predecessors. The pixel size for LANDSAT D will be 30 meters^2 as compared to 80 meters^2 for the previous and current LANDSATs. The reduced pixel size will allow us to do work with greater accuracy and also enable us to apply remote sensing to areas which are at this stage not well suited for this technique. For example, one can apply remote sensing quite effectively to temporal studies of land[*30] reclamation in east central Ohio[*31] but the same application to the strip mine areas in southeastern Ohio turns into a very frustrating task for the most part. In comparison, the strip mines in southeastern[*32] Ohio are generally much smaller and the researcher must, therefore, contend with a notably higher percentage of mixed pixel signatures which may lead to frequent misinterpretation. Studies for Belmont county in east central Ohio and Meigs and Jackson counties in southeastern Ohio have clearly supported this argument. The 30 meters^2 pixel size, about seven times smaller than the previous should greatly aid in the analysis of ground cover studies such as strip mine reclamation in southeastern Ohio.

LANDSAT D is the next satellite system that will provide researchers with new and expanded data about the earth.[*33] However, it will not be the last. The National Aeronautical and Space Administration is looking ahead and studying the needs of future earth resources. Various systems have been suggested and assessed to meet the needs between now and the end of the century. Basically, the systems are all aimed at eight major mission objectives: They are: Crop Production forecasting, grazing potential determination, timber stand volume estimation, geologic resource location, land use and census enumeration, watershed monitoring, water pollution detection, and disaster assessment.

Several space systems are under consideration to meet the above objectives. Among them are: GEOS,[*34] a Geosynchronous Earth Observation System; GEOSAR[*35] - a Geosynchronous Synthetic Apature Radar; a Radar Holographer[*36] - a bistatic microwave measurement system with geosynchronous illuminator and low orbit collectors which could provide a true hologram of the earth's surface;[*37] Earthwatch - subsynchronous (6000 nautical mile) multisensor vehicle could provide both mapping and quick-look capabilities for earth resources observation.

[*38] A Thermal Inertia Mapper would consist of two spacecraft which measure the thermal emissivity of the ground at 10 meters^2 resolution at pre-dawn and post-dawn opportunities to help identify and quantify terrain, indicate soil moisture content and aid in contrasting rock types. The[*39] SWEEP FREQUENCY RADAR,[*40] MICROSAT, the[*41] TEXTUROMETER, the[*42] ELLIPSOMETER and the FERRIS WHEEL RADAR are among other systems under study.

Another system under serious consideration by NASA is known as STEREOSAT. This system will be a free-flyer launched from the Western Test Range into a semi synchronous 713 km orbit projected for March 1984. The satellite design is based on the Multimission Modular spacecraft comparable to that to be used for LANDSAT-D. The instrument consists of three individual courses, one each pointed at the nadir and at 23° fore and aft. The focal plane of each camera will contain two silicon diode array yielding 4,096 elements across the spacecraft track. Each point on the ground will be acquired at different times by the three cameras and the resulting image triplet produces convergent stereo at the two base-to-height ratios of 0.47 and 7.0.

Stereosat has found strong support within the geologically minded user community for obvious reasons. A somewhat similar system, known as MAPSAT, was proposed by the United States Geological Survey in October of 1979.

Since the presidential directive, dated November 16, 1979, to assign the management responsibility for civil operational land-remote sensing activities to the National Oceanic and Atmospheric Administration (NOAA), it is reasonable to assume that the LANDSAT program will continue.

LANDSAT-H is considered a possible future LANDSAT system incorporating a so-called "smart" pushbroom scanner and a synthetic aperture radar for earth resources observation. The pushbroom scan sensor, also known as the Multispectral Resource Sampler (MRS) will provide us with even better information than that expected from the TM. To obtain an increase in temporal data it is financially most advantageous to utilize a sensor whose field-of-view can be directed to targets off the nadir in the across track direction. The MRS will be the first attempt to answer the science questions for a sensor of this type on a satellite platform.

Other drivers for this new sensor include: (1) provide higher spatial resolution than the TM, (2) provide narrower spectral bands and selectable bands to allow the MRS to be a facility for multi-disciplinary research, and (3) provide 0.5 percent sensitivity in the bands. A programmatic driver is to put all these characteristics into a package the size and data rate of the M.S.S. LANDSAT-H assumes the prior existance of LANDSAT-E, an operational version of LANDSAT-D, and LANDSAT-F and G optical and synthetic aperture radar developmental spacecraft, respectively. LANDSAT-H would have other unique attributes presently missing in the LANDSAT systems. One of them is an active visible imaging system called "nite-lite." This sensor will be used to provide atmospheric calibration of the push broom scanner, to investigate luminescence phenomena (both flourescence and phosphorescence), and to allow for the night imaging with the push broom scanners.[*43] Perhaps another SEASAT system will be launched to replace the first one which became nonfunctionalal in October 1978 after nearly four months of operation.[*44] Of course, the scientific community has high hopes for SPACE SHUTTLE with its multi-purpose mission. [*45]Which systems will actually be implemented and sent into orbit remains to be seen.[*46] Technologically, all the above mentioned systems are feasible by the end of this century for our advanced and sophisticated technology is nothing[*47] short of magic.

*47 slides accompanying this text can be obtained at cost from the author.

NASA

CORSE-81

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Customized Remote Sensing Short Courses

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Over the past fifteen years, remote sensing has moved from the concept phase of the mid-1960's, to an era of high data availability with the launching of Landsat in 1972, to the demonstration phase in the late 1970's, and, in this decade, toward sophisticated, operational applications. As remote sensing becomes a more significant part of the operations of an organization, the use of the technology inevitably becomes more specialized. The time has come for demonstrations to be replaced by technical assistance and by specialized programs which foster close cooperation between organizations to develop these specialized uses. The offering of general-purpose short courses, which are now available in many locations, can well be augmented by specially designed short courses which are prepared to meet the needs of a relatively small group, often from the same organization, and are presented at a time and place convenient for them. These customized short courses are the subject of this paper.

Advantages of customized courses over general-purpose courses

There are many reasons why an organization may turn to a customized course over a general-purpose course. If the employees of an organization all work in the same city, state, or even region, it is less expensive for a core of two to four instructors to travel to that location than to have the more numerous students travel to the course. Sometimes there are other reasons for choosing a special location; there may be a need for out-based staff members to return to a central office to become better acquainted with the staff and with facilities available there. Or it may be important for the course to be held at a well-staffed remote sensing center where students can see work in progress, learn about specialized equipment, or do hands-on exercises.

Customized courses also offer flexibility in scheduling. The timing of a course is often critical to an organization, whether the concern is scheduling a course for geologists when field work is not in progress or for project staff at the beginning of a project. Special requirements for course duration can be accommodated; while three-day courses or four-and-a-half-day courses are popular, other arrangements may be more appropriate in some situations.

LARS' experience in offering customized short courses extends over the past seven years. During these years, 13 different courses, summarized in Table 1, have been given in response to the specialized needs of many different organizations. Some courses followed the curriculum of the standard LARS short course on Numerical Analysis of Remote Sensing Data (2,8,9,10). Others were entirely new, composed of lectures and laboratory materials specially created to meet the objectives of the sponsoring organization (6,7). The focus and contents of each course were defined jointly with the sponsoring organization, with the statement of educational objectives of the course an important preliminary activity.

The paragraphs that follow address in more detail some of the features of these customized short courses.

Course Objectives

Probably the most obvious benefit to an organization in turning to a customized course lies not in questions of finance and convenience but in the shaping of the course content and level. The careful development of course objectives by the course coordinator and the sponsoring organization is an essential first step in defining what the course content and level must be. This ensures a clear understanding of the expectations of the organization for its employees at the end of the course and an agreement on the part of the course coordinator that these objectives are realistic given the length of class time and the previous experience of the students. Lacking these objectives, the students have no measure of what they are to learn and the sponsor has no measure of the accomplishments of the students.

In addition to these educational objectives, customized courses offer flexibility in meeting broader institutional objectives. In some cases customized courses are given as a part of long-term technical assistance to an organization (9,10,12); in other cases, they are given in conjunction with an organization's internal program to broaden the understanding and use of the technology (3,4,5,6,7). Some courses make up a sequence and are attended by the same employees (6,7); others are part of the training for new staff hired for a specific research program (12); others may be part of a longer course (8), blending with other sessions to achieve a homogeneous program for the students.

Course Development

Once the educational objectives are stated, course development can begin. A variety of paths may be followed for developing the course, with selection inevitably related to financial considerations. An organization whose needs match the objectives of the standard course or match it closely enough to select that program will be able to train its staff with little additional course development cost (2,8,9,10).[1] At the opposite extreme is the organization that has very specialized objectives and is able to support the development of an entirely new course (6,7). Between these extremes are the courses where existing educational modules can be used or slightly adapted to make up a large part of the course (3,5). When new materials must be developed, the cost of the course increases.

Another factor in course design is the educational level of the students, their previous experience with remote sensing, and the expected level of their performance at the conclusion of the course. Technically oriented students in applications jobs who are attending the course to gain a general understanding of remote sensing can be taught by any number of qualified instructors. However students in high-level research or management positions who are looking for more comprehensive training need to have contact with experts in specialized fields, both in lectures and in individual or small-group discussions. In some instances, consultants from outside the laboratory are engaged either as lecturers (3,5,12), laboratory consultants (10), or as partners in course development (6).

The success of a course depends in large measure on the understanding developed between the course coordinator and the organization. The following scenario would be an ideal way to achieve this kind of understanding. The sponsoring agency identifies one or two people within its organization who have experience in remote sensing and understand thoroughly the needs of the organization and the job responsibilities of the prospective students. The designated person (or persons) works closely with the course coordinator to develop the educational objectives and then to develop examples and/or laboratory exercises based on data and analysis objectives that the sponsoring organization is actually using. As long as appropriate reference data is available, a sample data analysis sequence could be performed and then documented by the appointee and the course staff. This plan would generally require a one-week residency by the appointee several months before the course is to be given.

This is a more costly approach for the sponsor, but the relevance of the course material to the organization's current work will motivate the students to take a more active part in the course and gain more from the experience.

Hands-On Exercises

When the course objectives can best be met through computer-based hands-on experience for the students, there are a number of approaches possible. In

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[1] It is worth noting that considerable flexibility is already built into the standard course. Ten hours a week are set aside for students to select individual learning activities from among a broad range of possibilities and an additional two hours are established as seminars with topics and presentors selected to appeal to the majority of the students present. (See "A Short Course on Remote Sensing," by Bruce M. Lube and James D. Russell, Photogrammetric Engineering and Remote Sensing, Vol. 43, No. 3 (March 1977), pp. 299-301.)

some instances the students need only an introduction to the use of various kinds of equipment; this is especially true for managers, where their needs are met by seeing a demonstration, discussing what they see with the operator, or perhaps getting limited hands-on experience. In other cases, course objectives point to a more technical approach, and extensive hands-on activities are needed that require students to work at computer terminals and operate other input and output devices.

Two major factors to consider when incorporating hands-on work are the availability of an appropriate analysis system and the scheduling of these potentially time-consuming individual activities within the course structure. Let's look first at the analysis system.

Accessing a full system is not complicated for courses held at research-based remote sensing centers where the analysis software has been developed, implemented or made available through a remote terminal network and the hardware is in place. Courses held away from these centers can use either a mobile training unit, such as the one developed by the Western Regional Applications Center, or a temporary remote link to a large system (8,10,12), with dial-up terminals leased for the duration of the course. Access to a major analysis system means that student exercises may be based on current software on the host computer and may draw on large quantities of aircraft and satellite multispectral data available in the associated data base.

Some organizations prefer that students gain hands-on experience on their own systems, and this request can also be accommodated through customized courses (6). Since many of the same concepts underlie all remote sensing analysis, regardless of the specific system, the general content of the exercises can often remain the same with only variations in the specific commands and interactions with the systems.

Scheduling hands-on activities during the course requires care since this work can absorb much student and instructor time and can be one of the most costly aspects of a course. In our experience, students require a minimum of five hours to gain familiarity with the hardware and enough of the software and its documentation to be aware of the major features of the system. When a complete analysis is done, even when carefully selected and prepared by the instructor ahead of time, ten to fifteen hours of hands-on time may be needed per student, depending on his background and the objectives of the course. Several user terminals are needed if all people in a standard-size class are to have a reasonable amount of hands-on time within the framework of the course. The decision to include hands-on activities needs to be carefully weighed against the course objectives and the resources available. There is no substitute for the experience gained in this way or for the sense of confidence it gives in one's ability to use the technology.

Special Requirements

We have discussed some options related to content, level, location, duration, and timing of the course, but there are often, in addition, other specific conditions that can be met through customized short courses. For example, courses for Spanish-speaking students have been presented in that language, with translation of all visuals and supportive materials (2,8,9) and simultaneous translation for non-Spanish-speaking lecturers. Some organizations require that students pass a test at the end of the course as evidence of their accomplishment (3,5,8). In another case, the sponsor wanted two specific courses developed, presented, and documented fully enough for instructors from within that organization to be able to teach the course in the future (6,7). In addition to supplying annotated slides and overheads, the course was completely videotaped to meet that requirement. While the videotapes were not edited or prepared in any way for student consumption, they can give a prospective instructor a sense of the pace of the presentations, the features pointed to on slides, the student questions and responses, and impromptu blackboard diagrams created in response to questions.

In short the features of customized courses can be altered to meet nearly any learning requirement. The objectives of the course provide guidance to the course coordinator in making specific decisions about content, level, and format within the constraints of the available funding.

Ensuring the Quality of the Course

Creating new, specialized courses and presenting these effectively is expensive. Releasing employees from their normal tasks is also expensive. And travel, if required, is always a significant cost. It is critical, therefore, that any course be well-conceived, be relevant to the work of the students, and be expertly presented.

Excellent courses will most likely, we believe, come from a university, where good teaching and research are part of the mandate. When a group of scientists has experience in many types of remote sensing research, the kinds of perceptions and knowledge that are developed are inevitably shared throughout the laboratory. This research may encompass sensor design and spectral measurements, as well as analysis algorithms and specific applications. In many instances specialists may be available to address the class or work with students one-on-one or in small groups.

In a university, too, the many opportunities to teach remote sensing to a variety of groups foster carry-over from one course to another. Once good tutorial materials are developed for a topic, they may often, with only minor changes, be used for another course. The availability of a body of such materials for laboratory exercises is especially important since the development of good materials, with appropriate data and imagery, can be extremely time-consuming.

The university offers still another advantage to an organization seeking special courses. In subjects where the remote sensing staff may not be experienced, such as photogrammetry or meteorology, there are often other experts within the university who can be drawn in. The university's ability to hire outside consultants opens the door still further for acquiring very specialized expertise.

Effective courses are most possible when the offering organization meets as many as possible of the following criteria:

1. Depth and breadth of research experience and applications in remote sensing;

2. Wide experience in remote sensing education and the flexibility to construct courses from a variety of resources, both personnel and well-tested educational resources;

3. The legal and accounting support to handle contractual matters and to draw on talented scientists outside the contracting agency;

4. An educational philosophy that requires a clear statement of educational objectives as a guide to all involved in the course as sponsors, developers, or students.

Summary

Many organizations are now recognizing a need to expose their staff to remote sensing technology but feel, because of the size of their organization or the specialness of their needs, that a customized course would be more appropriate than a general-purpose course. With increased sophistication in the use of remote sensing, short courses are frequently a part of a broader-based technical assistance program. A versitile organization with research depth and a commitment to excellence in education can respond effectively to these requirements.

Table 1. Summary of customized courses offered by LARS, 1975 to the present (reverse chronological order)

	Course Title	Sponsoring Organization	Duration (Days)	Location	Special Features
1.	Reformatting Programming	National Institute of Investitions of Biotic Resources (Xalapa, Vera Cruz, Mexico)	5	LARS	Focus on implementation of digital preprocessing capabilities
2.	Numerical Analysis of Remote Sensing Data	International Atomic Energy Agency	4½	Santiago, Chile	Focus on mineral exploration. Spanish language lectures and teaching materials. Simultaneous translation of English lectures
3.	Advanced Digital Image Processing and Analysis	Corps of Engineers	5	LARS	Continuous classroom interactive demonstration of terminal capability. Inclusion of Corps-related topics
4.	Remote Sensing Manager	Corps of Engineers	3	W. Lafayette	Topics selected to meet needs of managers and presentations made by remote sensing managers. Emphasis on water resources
5.	Remote Sensing Fundamentals	Corps of Engineers	5	W. Lafayette	Emphasis on water resources. Strong guidance in course format and content by sponsor
6.	Remote Sensing for Mineral Specialists-Digital Analysis	Bureau of Land Management	4½	Denver	For geologists. Entire course specially designed and documented for future in-house instruction. Hands-on experience using the IDIMS
7.	Remote Sensing for Mineral Specialists, Visual Interpretation	Bureau of Land Management	4½	Denver	For geologists. Entire course specially designed and documented for future in-house instruction
8.	Numerical Analysis of Remote Sensing Data	Defense Mapping Agency/IAGS	4½	Panama	One week of 6-week intensive program. Spanish language lectures and teaching materials. Simultaneous translations of English lectures. Hands-on exercises via dial-up remote terminal link to LARS
9.	Numerical Analysis of Remote Sensing Data	Inter-American Development Bank	4½	LARS	Given entirely in Spanish. The two representative from each Central America country did hands-on exercises using data from their own country
10.	Numerical Analysis of Remote Sensing Data	NASA	4½	JSC	Hands-on via dedicated remote terminal link to LARS
11.	LARSYS Programming Short Course	Commission on National Plan for Hydrology, Mexico City	7	LARS	Preparation for modifying and implementing LARSYS. Hands-on in Spanish
12.	LACIE Short Course	NASA	25	JSC	To train project analysts for a specific application. (offered twice)
13.	Remote Sensing Technology and Applications	IDRC	4½	LARS	Taught in Spanish. Introduction to long-term technology transfer activity. Used Bolivian data for hands-on exercises

CORSE-81

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MULTIMEDIA IN REMOTE SENSING EDUCATION

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ABSTRACT

Professional experience in teaching digital remote sensing techniques to new users has shown the value of a multimedia approach to technology transfer. In this report, the use of computer-generated data and graphics paired with color 35mm slides in a multimedia presentation will be discussed. The combination has proven to be effective in a statistics presentation.

INTRODUCTION

A successful multimedia presentation of the concepts of basic statistics applied to remote sensing digital classification and analysis is reported for the benefit of those interested in teaching the digital (computer-assisted) processing of Landsat multispectral scanner data. The presentation uses side-by-side graphic displays, on the one hand generated in real time by an Apple II microcomputer and on the other hand projected from prepared 35mm color slides, as well as vocal descriptions and discussions while the graphics are being displayed. The presentation was developed at the Eastern Regional Remote Sensing Applications Center (ERRSAC) at the National Aeronautical and Space Administration (NASA) facility at Goddard Space Flight Center (GSFC). It has been used in training programs conducted there.

The multimedia presentation uses equipment available from the Apple Computer, Inc. company and from the Kodak Company. The computer consists of the Apple II micromainframe with auxillary language cards (READ ONLY MEMORY (ROM)) and a television monitor used as a color display device for the computer-generated graphics. The Kodak equipment consists of a set of 35mm color slides, designed and photographed by ERRSAC personnel using Kodak film and processing, and a Kodak "EKTA-GRAPHIC" slide projector. Although designed for the Apple II microcomputer and Kodak projection equipment, the multimedia presentation could be implemented on any of several commercially available microcomputers and slide projectors.

A technical document which covers similar material in a parallel fashion is distributed to each student. The document provides review and reinforcement.

DISCUSSION

The multimedia presentation of basic statistical concepts is suitable for presentation to large groups, small groups, and for individual instruction. For large groups, a projection television monitor should be used so that the computer-generated graphics are as visible as the projected 35mm color slides. For small groups, standard large-screen television monitors and slide projectors should be used. In both cases, equipment should be set up in advance and the speaker should make a trial run. For individual instruction, the speaker's script should be taped; the tape should include "silent sound" prompts for the automatic advancing of slides on an audioviewer and normal prompts for advancing the computer program.

Basic statistical concepts covered in the presentation include the following:

- The need to use statistics to describe a large data set
- Use of statistics to make predictions, usually about land-cover classification.
- Use of statistics for graphic displays:
  - bar graph and histogram
  - scatter diagram
  - line graph
  - pie chart
  - rose diagram
- Calculation of data set (sample) statistics:
  - range
  - central tendency:
    - average (mean)
    - median
    - mode
  - scatter:
    - standard deviation
    - variance
  - bivariate statistics:
    - vector space distance
    - covariance

Student comments, especially from those without a background in statistics (the target audience), have been generally favorable.

CONCLUDING REMARKS

A multimedia presentation using live, computer-generated images with 35mm color slides has proven to be effective in teaching the basic statistical concepts needed for computer-assisted remote sensing image processing.

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PERFORMING AND UPDATING AN INVENTORY OF OREGON'S EXPANDING IRRIGATED AGRICULTURAL LANDS UTILIZING REMOTE SENSING TECHNOLOGY

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Introduction

Recently the Oregon Water Policy Review Board directed the Oregon Water Resources Department (OWRD) to prepare inventories of current water use and projected water needs throughout the State of Oregon for the purpose of developing baseline data fundamental to water policy formulation. Basic to the inventory procedure is the need to assess land use activities in order to determine where water is currently being used, lands presently being irrigated, and where water will potentially be used, lands potentially irrigable. To secure necessary baseline data the inventory calls for: a) compiling detailed land use maps of the state by drainage basin, b) tabulating land use data in acres by basin and county, c) preparing interpretation aids and collecting collateral data to support the initial inventory and to facilitate future inventory updating activities, and d) developing methods for updating the inventory.

Upon completion of the inventory, the next step in formulating water policies is to survey the presently non-irrigated agricultural lands and rangelands identified through the inventory to determine if they contain irrigable soils. Potentially irrigable land acreages are tabulated and their spatial distribution and available water potential are analyzed. From this point, designs for water supply systems for potentially irrigable lands are planned and economic feasibility studies are made examining irrigation costs, alternate cropping practices, water consumption, revenue return, etc. Finally, presentation of these reports is made to local citizen advisory committees and to the Water Policy Review Board for the purpose of water policy formation.

In 1978 the Oregon Water Resources Department approached the Environmental Remote Sensing Applications Laboratory (ERSAL) with the task of compiling formulation procedure. In 1977, prior to this contact, OWRD and ERSAL jointly completed a land use mapping project of the Umatilla and Hood River Basins of Oregon. During this project, entitled the Columbia River Water Policy Project, they developed an inventory technique based upon using remote sensing technology, interpreting both high altitude aerial photography and Landsat multi-spectral scanner (MSS) imagery. The current project, underway since October 1978, is modeled after the 1977 Columbia River Project. During the past 2½ years the remainder of the state (with the exception of the South Coast Basin) has been inventoried.

The Inventory

Land cover types are delineated on aerial photography, updated with Landsat imagery, transferred onto base maps at ERSAL and then turned over to OWRD where the land use polygons are measured and the area acreages tabulated by basin and county. The tabular data will be presented to the Oregon Water Policy Review Board. The map data will then undergo further analysis, land use data being correlated with soils data. In addition, final land use maps are being constructed for each drainage basin.

The land use classification scheme adopted for use in the inventory is a modified version of the first level of that developed by Anderson et al. (1972) in "A land-use classification system for use with remote-sensor data," U.S. Geological Survey Circular 671. Land cover types were interpreted and delineated from (on) remotely sensed data and land use inferred from cover types and appropriate collateral data. The land use types inventoried were: irrigated agriculture, non-irrigated agriculture, forest land, rangeland and unimproved pasture, urban, water, and other (including several subclasses).

NASA high altitude color infrared aerial photograph transparencies at a scale of 1:130,000 (one basin is covered by film at a scale of 1:63,360) were used in the inventory. Land cover type units were delineated to ten acre minimum sized parcels. The aerial photography provided the necessary spatial detail but varied in date of acquisition from 1972 to 1980 and from

April to September. Current land use activities which differ from those on dated photography are detected by interpretation of Landsat MSS imagery. Land use patterns delineated on the aerial photography were updated by visual means using three-band (4, 5, and 7) false-color composite transparencies at a scale of 1:1,000,000. Multi-temporal Landsat collected through the growing season provided timely data necessary for differentiating crop types, for example, irrigated from non-irrigated croplands. In addition, the relative recency and large areal coverage of Landsat data made it possible to update the entire region to the same approximate date.

The training of photointerpreters in land use analysis in a state such as Oregon with diverse land use activities is critical to the success of the inventory. Field trips were taken throughout the state during which over 400 pre-selected field sites of a variety of land use types were photographed at various stages through the growing season and field observations recorded. The field sites were selected such that about 75% of them represented characteristic photo signatures on the aerial photography and 25% represented unique or problem signatures. The field data were organized into card sets by basin, each containing photographs of crops at various growth stages through the growing season, locational maps of the photo sites in the fields, height and condition of the crop and any evidence of irrigation. The card sets were organized so that they could be used at individual photointerpretation (PI) stations. In addition, slides were taken at the same sites (in some cases color infrared slides) for use in training groups of interpreters. The slides are shown simultaneously with projected (overhead projector) vertical aerial photography to help the interpreters make the transition from recognizable ground scene to vertical photo signature. Additional training aids included crop calendars derived from consultation with county extension agents and appropriate publications.

After the completion of land use photointerpretation training sessions and area familiarization, land use classes were photointerpreted and delineated on mylar photo overlays using Old Delft Scanning Stereoscopes (ODSS III). To insure consistency of delineation, two interpreters viewed the same photo simultaneously using the ODSS III stereoscopes face to face. Before initiating photointerpretation, the photo overlays are marked with the map boundaries they are to be transferred onto; in addition, major roads and other landmarks are plotted in a different ink than is used in the land use delineations, methods to facilitate registration of the photo overlays to the maps. Upon completion of the photointerpretation, the work was edited to insure continuity of the data surface. The interpreted polygons were checked to see that all were labeled, closed, and where a polygon continued from one photo to an adjacent one that the delineations matched.

The photo delineations were updated using Landsat MSS imagery. The dates of imagery for each basin were chosen with the aid of crop calendars, such that optimal data could be acquired for distinguishing land use types, particularly irrigated from non-irrigated agricultural lands and non-irrigated agricultural lands from rangelands. Multidate scenes were needed in most basins.

Updating was accomplished in some cases using a Zoom Transferscope, but in most cases it was done using an 8X Agfa Lupe hand lens. Aerial photo equivalent area masks were placed over the Landsat transparencies to facilitate feature location.

After the updating with Landsat data was completed the frames were edited again and the transfer procedure initiated. The photo derived data were transferred onto U.S. Geological Survey 7½' orthophoto and 7½' and 15' topographic quadrangles, in that order of availability. Highly complex small areas with many landmarks were transferred using a Zoom Transferscope. Large areas with few landmarks were transferred by photographing the photo overlays and projecting the resulting 35 mm slides onto a mirror and down to the map surface. The landmarks enable the non-geometrically corrected photo overlay to be registered to the rectified maps. The maps were edited again for the third time. Then they were turned over to OWRD where the land use polygon areas were measured and final products constructed. When planimetered the data transferred onto the orthophotoquads must be adjusted because the orthophotoquads available for most of Oregon are advance prints made through an ozalid process and thus are slightly larger scale than the published 1:24,000 orthophotoquads.

Updating the Inventory

A statewide land use inventory by its very nature is a one-time glimpse at a dynamic process, fixing one view in mind at the time the inventory was accomplished. The inventory must be updated periodically to remain useful. Satellite imagery (Landsat RBV and MSS) are ideal media by which to update the inventory. Of particular interest to the Oregon Statewide Land Use Inventory is the changing status of irrigated agriculture in the state. A pilot study was made using Landsat-3 Return Beam Vidicon (RBV) imagery to detect change in irrigated agricultural land in the Fort Rock and Christmas Lake Valleys of Lake County, Oregon from 1978 to 1980. In this case aerial photograph delineations were initially updated to 1978. Since the final basin map was not prepared by the time the RBV exercise was completed the photo data were transferred directly onto a 1:125,000 1978 Landsat RBV subscene. RBV subscenes from 1979 and 1980 were acquired at the same scale. The original overlay was updated to these two additional dates and a composite of additive change constructed. In this particular area two important factors facilitate the updating task, a) most of the irrigated parcels are large (over 80 acres) and many of them take the form of center pivot systems, and b) a great deal of change is occurring in this area. When the RBV image was enlarged to 1:125,000 a township and road grid was superimposed on the prints making the registration of the various dates much easier. Although the township and road grid was probably not necessary in this area because of the abundance of natural landmarks it may be useful in areas with fewer identifiable features. In addition, such a step would facilitate ground checks in support of the updating procedure. Once final land use inventory map separates of irrigated agricultural lands are available and scaled to either 1:250,000 or 1:125,000 they may be overlaid directly onto either MSS or RBV prints and additions or deletions may be noted on the overlay. This is an inexpensive process that for most areas would not be too time consuming.

Summary

Remote sensing technology provides many useful tools for performing and updating land use inventories. Spatially detailed aerial photography, seasonally available Landsat imagery and carefully collected ground level data combine to give an accurate, overall, and updated view of land use conditions. The availability of Landsat imagery provides an excellent opportunity for future inventory updates once the initial data base is established.

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CORSE-81

The 1981 Conference On Remote Sensing Education
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Low-cost Digital Image Processing at the University of Oklahoma

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Introduction

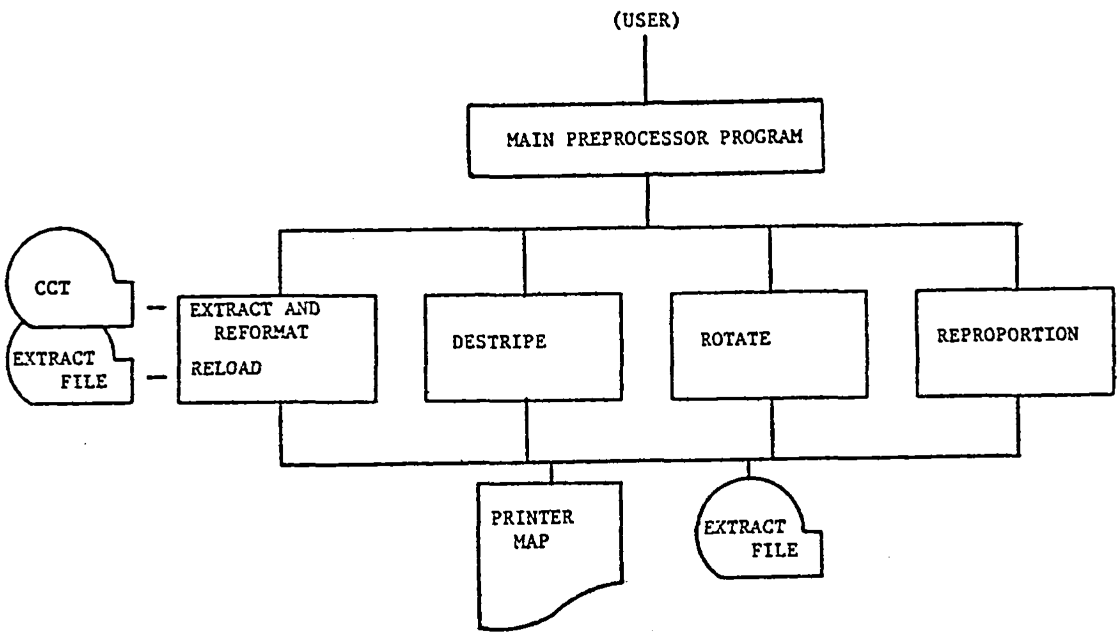
Computer assisted instruction in remote sensing at the University of Oklahoma involves two separate approaches and is dependent upon initial preprocessing of a Landsat computer compatible tape using software developed for an IBM 370/158 computer. In-house generated preprocessing algorithms permit students or researchers to select a subset of a Landsat scene for subsequent analysis using either general purpose statistical packages or color graphic image processing software developed for Apple II microcomputers. This paper describes procedures for preprocessing the data and image analysis using either of the two approaches for low-cost Landsat data processing.

Preprocessing

At the time of project initiation, a suitable Landsat CCT preprocessor software package for use with an IBM 370/158 computer system was unavailable. Hence, efforts were expended to produce a transferable remote sensor data extraction and analysis software package written in ANSI standard Fortran IV. The now accomplished initial goal produced a set of preprocessing algorithms with options similar to software packages designed for dedicated mini-computers (Figure 1).

LANDSAT CCT PREPROCESSOR

Figure 1



Package requirements include: one tape drive, a maximum of 276 K of CPU memory, and at least 60 cylinders of disk space on an IBM 3330 disk pack or equivalent. Tape copies of the preprocessor program with documentation are available from the University of Oklahoma's Landsat Training Program at the cost of duplication and materials. On-going software development is aimed at producing a series of subroutines that will search an extracted data set and generate an unsupervised classification.

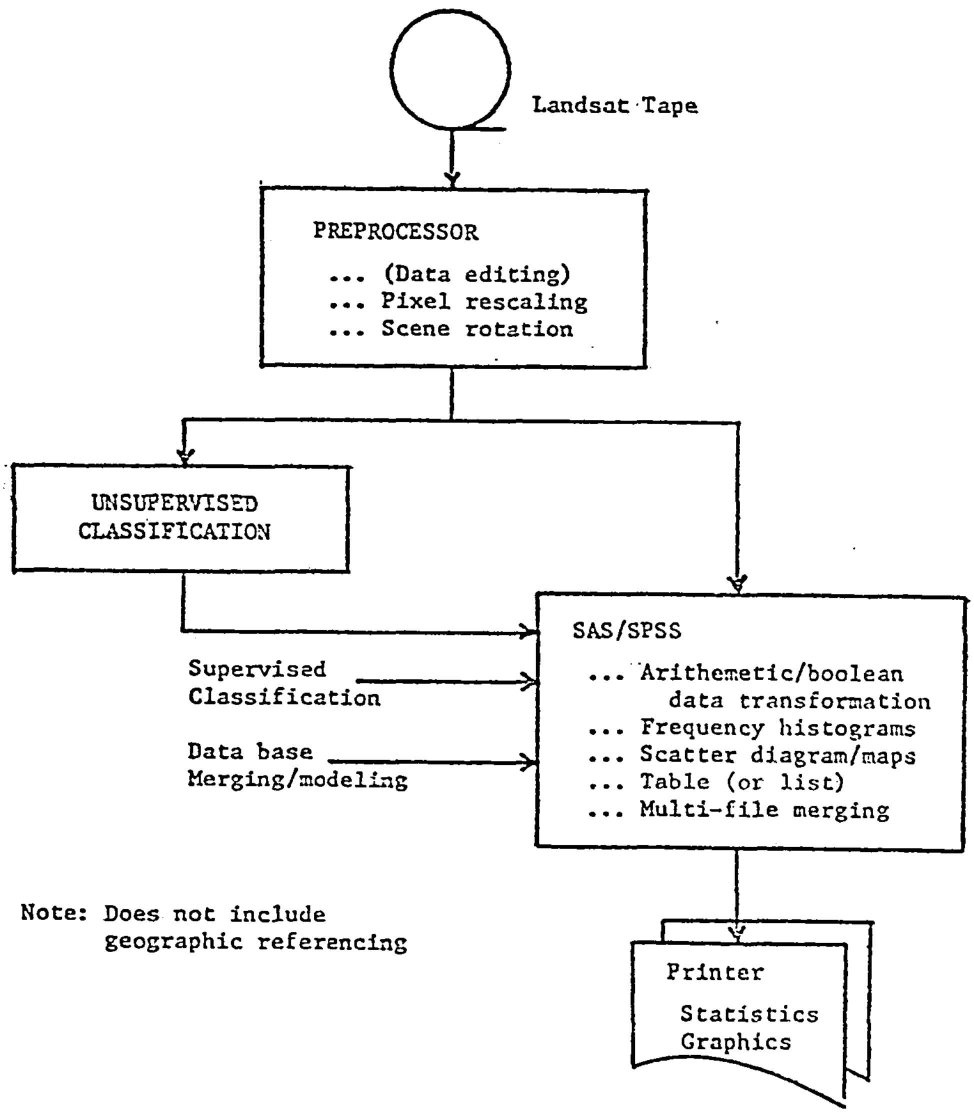
The major purpose of the currently available preprocessor software package is to extract a relatively small geographical area from a Landsat data tape. Preprocessing of the satellite remote sensor data accomplishes several necessary tasks; due to both memory storage limitations and input format specifications of subsequent analysis routines, the extraction subroutine restricts users to selection of a polygon of up to fifty sides that lies within a 300 by 300 pixel window. The routine also rearranges the original data matrix into a pixel oriented record format which resembles an 80 column, card file; each record or card contains scan line number, element number, and the four reflectance values for an individual pixel. Optional subroutines available in the preprocessor package allow 1) production of line printer maps of individual bands of data, 2) rotation of the data set to align the matrix so that it is north-south oriented, 3) modification of the data set to correct for sensor calibration error (destriping), or 4) reproportioning the data to adjust the pixel size and, hence, change the scale of the line printer output.

General Purpose Statistical Packages

Data sets created through use of the preprocessor package are easily input into either the Statistical Package for the Social Sciences (SPSS) or the Statistical Analysis System (SAS) for analysis (Figure 2).

Figure 2

A MINIMAL COST
CLASSROOM INSTRUCTIONAL/PRELIMINARY RESEARCH
IMAGE PROCESSING SYSTEM
USING EXISTING STATISTICAL PACKAGES



Landsat data analysis at the University of Oklahoma has primarily involved the use of SAS in an interactive environment. Statistical tabulations, histograms, and maps of the data have all been produced using this system. An important aspect of SAS is its ability to compute new variables based on the existing data; creation of ratio data or the use of regression equations to generate predictor variables that depict the spatial variability of certain phenomena are easily accomplished. Estimates of the distribution of turbidity within several Oklahoma reservoirs have been produced using an equation that correlates turbidity with Landsat bands 4, 5, and 7 (Grimshaw, et al., 1980).

Additionally, this ability to create new variables allows users to simulate a supervised classification of remote sensor data. For example, if an analyst knows that water has a band 7 reflectance value less than 20 and that separation of clear from turbid water is based on a band 5 value of 15 or less, then these two different cover types can be distinguished with just two statements in the SAS job stream. Following data definition in SAS, the plot procedure allows the user to generate a map of the distribution of water or other similarly defined cover types.

Use of general purpose statistical packages in an interactive setting allows students to get "hands-on" digital data analysis experience and provides an efficient method for demonstrating spectral, spatial, and radiometric variability in the data (Jensen, et al., 1979). Use of an already available computer system and general purpose statistical packages results in effective computer assisted instruction at minimal additional cost to the instructor or the educational institution involved.

Microcomputers

Digital processing of remote sensor data relies heavily on color image display in both interpretation and classification. Even though color displays are not essential to the analysis, they greatly facilitate the pattern recognition process and allow generation of highly marketable finished products. Incorporation of low-cost color image display capabilities into remote sensing instruction at the University of Oklahoma was accomplished through the use of a 48 K RAM Apple II microcomputer, an Apple II disk drive, a color T.V., and an Apple communications interface and acoustic modem (for Landsat data transmission to the Apple for storage on diskette).

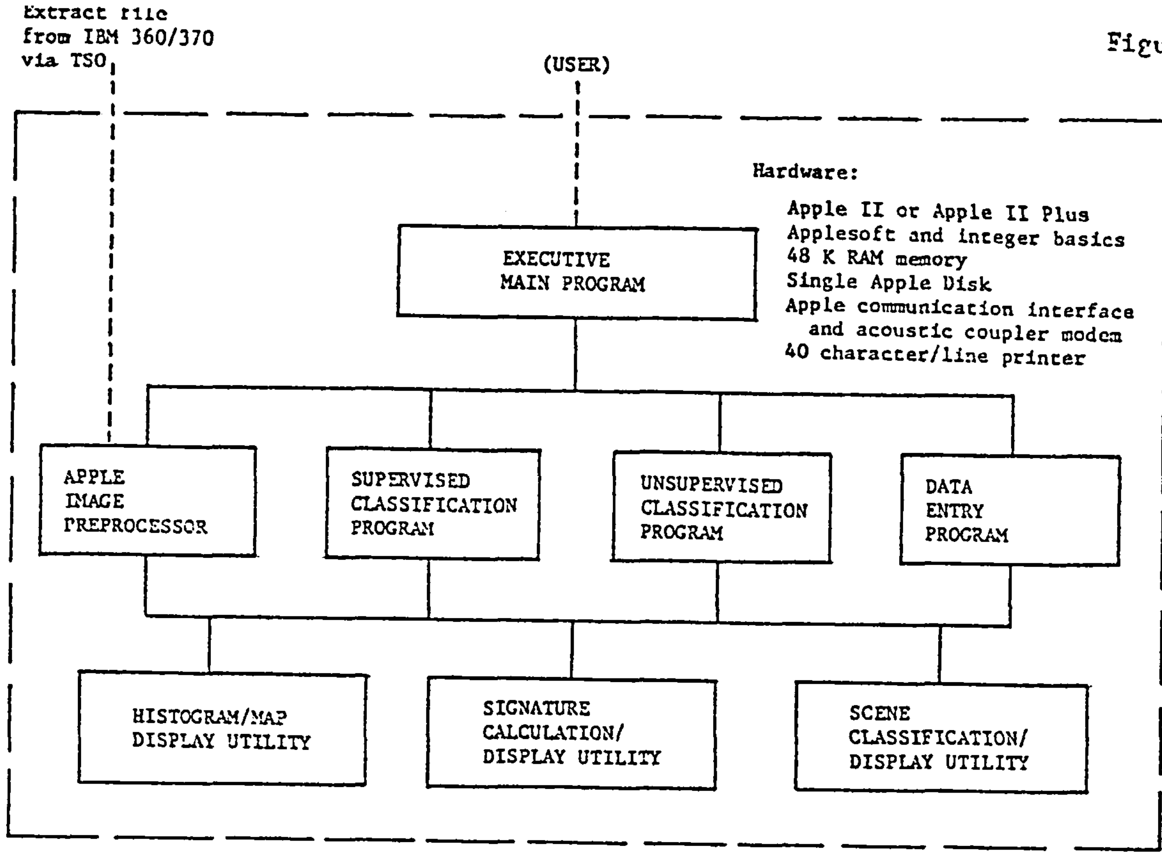
Ongoing programming is aimed at producing a software package which 1) preprocesses the data, 2) produces a supervised or unsupervised classification, 3) allows entry of ancillary data, or 4) generates several different types of color image products (Figure 3). Initial software development was undertaken to test the feasibility of using Apple II microcomputers for digital image processing. Routines were developed to 1) transmit a small data set from an IBM disk file to the Apple II for storage and subsequent analysis, 2) produce a histogram of reflectance values for any of the four bands, 3) generate a two-space plot of band 5 versus band 7 reflectance values, and 4) density slice an individual band with the analyst selecting the cut-off values for the various color breaks.

Use of the Apple II microcomputers in remote sensing classes has greatly facilitated the learning process. Students indicate that "hands-on" experience associated with computer assisted instruction helps clarify many misconceptions that can be generated in the usual slide-lecture learning environment. Individuals asked substantially more questions and several were stimulated to improve existing programs and experiment with writing their own software routine(s).

Summary

Low-cost digital image processing capabilities developed for remote sensing instruction at the University of Oklahoma are based on three separate software packages. Initial data handling is accomplished through preprocessing algorithms written in-house for an IBM 158/370 computer. Subsequent analysis is accomplished using either general purpose statistical packages

Figure 3



APPLE LANDSAT PROCESSING PROGRAM SCHEMATIC

such as SPSS and SAS or an Apple II microcomputer with its color image display capabilities. Equipment costs associated with this instruction package amount to less than $5,000.00; all other costs (programming, computer time) were absorbed by the University.

Acknowledgements

This work was supported in part by NASA Contracts NAS 13-85, 13-122, and 13-156.

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PROJECT OMEGA

AN INTRODUCTION

by

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With the advent of Landsat satellites, the stage was set for classroom revolution in map skills. When it became clear that Landsat was not merely a passing interest in the U. S. Space Program but a reliable source of continuously updated imagery, its obvious educational implications began to be seriously examined.

Since 1975, research in remote sensing education has been underway at the University of Alberta's Faculty of Education to determine students' capabilities to work with Landsat satellite imagery. Originally, it began with research dealing with the elementary level but has now expanded to all levels of education including adult. It encompasses three departments: elementary education, secondary education, and educational psychology. Project Omega attempts to do two things: determine the capabilities of people to work with Landsat and other remote sensing elements, and to develop procedures for training people to work with them and teach others to work with remote sensing imagery and equipment. The only limitation is that research deal primarily with an educational concern rather than a technological one.

As a Faculty of Education, we welcome all educators and technicians interested in research in remote sensing education. It is not expected that masters and doctoral candidates necessarily have a strong background in remote sensing, although it does help. Where candidates have little or no background in this area, they are expected to take the Alberta Remote Sensing Center's annual short course or its equivalent.

Omega Research in Remote Sensing Education has included the abilities of elementary level pupils to work with Landsat Color 1 and Band 5 imagery, Color 1 in-service teacher training via distance education, and Computer-Assisted Instruction for Pre-Service Teachers. Presently, research is underway to determine elementary level children's abilities to undertake Landsat multispectral examinations.

We welcome your inquiries, and a brief bibliography is yours for the asking.

NASA

CORSE-81

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GROUND PHOTOGRAPHY FOR IMPROVED IMAGE INTERPRETATION TRAINING

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This study was supported by the State University of New York Research Foundation.

Systematic sets of ground based color and color infrared photography were presented to students in remote sensing classes to enhance their ability to interpret satellite images. Features readily apparent on computer enhanced LANDSAT images were presented simultaneously with ground based photography in the format of slide triplicates. It was hypothesized that this instructional approach would improve the students' abilities to recognize, understand and interpret ground phenomena present on remotely sensed imagery. Tests conducted in undergraduate remote sensing classes substantially upheld this hypothesis. Student image interpretive abilities were tested before and after being exposed to the ground level photography. In general, image interpretive skills of the class improved by 25%. It is interesting to note, however, that the performance of students having different academic majors varied greatly for differing types of image subjects.

Student inability to associate patterns present on remotely sensed imagery with familiar phenomena of the earth's surface hinders their development of image interpretive skills. It was thought that students would more readily understand the data collection processes which produce remotely sensed images, and would be better able to interpret various forms of remotely sensed data, if they were also presented with numerous low altitude and ground based photos of phenomena present in the imaged scene.

Slide sets of low altitude and ground based images, with accompanying satellite imagery, were prepared to illustrate ground phenomena present in the satellite image. These near-ground photos would ease the spatial and spectral shock often experienced by students when observing small scale, and exotic, remotely sensed imagery for the first time.

This approach to improving the instructional content of geography remote sensing classes was tested in 1980 with a small award for the improvement of undergraduate instruction from the State University of New York Research Foundation. Extensive ground photography, collected during the summer of 1980 in Colorado, was presented to students in two remote sensing classes as sets of slide triplicates. Each projected image scene was accompanied by standard color and color infrared slides of the same ground point. Students' image interpretive ability improved significantly with the use of ground level photography, and this enhanced ability developed into a better understanding of remote sensing technology and image interpretation in general.

During the first semester of this project over 133 undergraduate students were directly affected. Thirty five students in "Remote Sensing - Theory and Techniques" (Geo. 280), and thirty three students in "Remote Sensing - Image Applications" (Geo. 380), were extensively exposed to slide sets, photo prints, and other materials throughout the course of the semester. Sixty five students registered in "Physical Geography" (Geo. 110) were also exposed to some of the products of this project during that portion of the course which employed the use of remotely sensed imagery.

In general students have responded with very positive comments. They seem to enjoy the subject matter, and unique style of presentation, of the materials developed for this project. Thirty six students in the "Remote Sensing - Theory and Techniques" course were asked to provide written comments concerning the value of ground level photography, developed with the support of this grant, to improve their image interpretive abilities. The majority of the students classified themselves as having "very little" to "no" familiarity with aerial photography and remotely sensed images. Only one of these 36 students indicated that he found the "availability of color, false color, and aerial imagery...did more to confuse" than clarify. This student also indicated that he had very little background in geography and the subject matter under study. It is interesting to note that this is the single History major who, on the comparison of pre and post tests, shows remarkable improvement after disasterous pretest scores.

Students of the Remote Sensing classes (Geo. 280 and 380) were presented with a set of test slides involving 66 satellite image scenes. Each scene was projected simultaneously with ground level slides of the same subject in both color and false color. One set of 33 slide triplicates was used as a pretest. The pretest initially involved only the satellite scenes, without accompanying ground level photos. A second set was used to test increased interpretive abilities of students after having been exposed to the full explanation of the previous set of slides. These slide sets proved to be a good test of the usefulness of the materials, and an excellent instructional aid.

A table of the results of these tests displays 25% improvement for the class as a whole. It is interesting to note that the performance of students having different academic backgrounds varied greatly for differing types of image subjects. This observation will be the subject of future research.

A similar set of tests was administered to 65 students in the "Physical Geography" (Geo. 110) class. This test consisted of 32 slide triplicates. The performance of this class showed a 33% increase after being exposed to the ground level photography developed by this project. It is interesting to note that the same set of tests and materials was presented to a group of College geography teachers, who's scores improved 21%. These College geography teachers had little familiarity with remote sensing, and were attending a Remote Sensing Workshop sponsored by the National Council for Geographic Education, which the principal investigator of this project helped to teach.

Perhaps this newly tested instructional approach is more important than the photographic materials themselves. Tests already conducted have shown that students are able to understand remotely sensed imagery much better if they are also shown ground level scenes from the same area. Since remotely sensed images have now become commonplace in many geography courses, the knowledge gleaned from the work supported by this grant will be applicable to the general instructional techniques of all geography classes.

In a more general context, the work of this study supports the idea that students are more readily able to understand and relate to information which most closely parallels their personal experience. Thus, instructional materials of an abstract nature, such as maps and remotely sensed images, may well be enhanced with the use of standard photography. Instructors should be cognizant of the fact that students are not necessarily equipped to instinctively decode and interpret abstract patterns of form and color, translating this information to real life experience. If the transition from abstract form to personal experience is difficult for some students, then the automatic comprehension of foreign lands and strange environments, as presented on maps and remotely sensed imagery, can not necessarily be expected.

COMPARISON OF PRE & POST TESTS
FOR UNDERGRADUATE REMOTE SENSING CLASSES
(% IMPROVEMENT)

	TOTAL EXAM	TERRAIN FEATURES	LAND USE/ LAND COVER	LAND MANAGEMENT ACTIVITIES
FULL CLASS	25%	48%	-4%	27%
GEOGRAPHY MAJORS	24%	61%	-9%	24%
GEOLOGY MAJORS	39%	159%	-28%	27%
BIOLOGY MAJORS	16%	-7%	29%	32%
HISTORY MAJOR	178%	127%	38%	911%
UNSPECIFIED MAJORS	-7%	13%	10%	-5%

IMAGED TEST SUBJECTS

TERRAIN FEATURES

- CANYON
- RIDGE
- CIRQUE AND/OR MT. PEAK
- VALLEY FLOOR
- WEST FACING SLOPE
- EAST FACING SLOPE
- ALLUVIAL FAN
- TREE LINE
- BARE ROCK
- RIVER
- LEVEL (FLAT) REGION
- MOUNTAINOUS REGION

LAND USE OR LAND COVER

- RANGELAND GRASSES (STEPPE)
- IRRIGATED CROPS
- DROUGHT RESISTANT CROPS
- WATER
- URBAN COMMERCIAL & INDUSTRIAL
- URBAN RESIDENTIAL
- DECIDUOUS FOREST
- CONIFEROUS FOREST
- TUNDRA
- SNOW & ICE
- CLOUDS

LAND MANAGEMENT ACTIVITIES

- SKI AREA
- INTENSIVE (IRRIGATED) AGRICULTURE
- EXTENSIVE (RANGELAND) AGRICULTURE
- MULTIPLE USE HYDROLOGIC MANAGEMENT (RECREATION AND WATER SUPPLY)
- HIGHWAY
- RAILROAD
- LOGGING
- GOLF COURSE
- WILDERNESS
- IRRIGATION CANAL
- ELECTRICAL POWERLINE RIGHT-OF-WAY
- MINING

CORSE-81

The 1981 Conference On Remote Sensing Education

May 18-22, 1981 Session No. 3

LABORATORY EXERCISES, REMOTE SENSING OF THE ENVIRONMENT

PRESENTED BY Olin Mintzer and John Ray

The exercises are designed to convey (1) principles and theory of Remote Sensing, and (2) methodologies of its application to civil engineering and environmental concerns, including agronomy, geograpy, geology, wildlife, forestry, hydrology, and other related fields.

During the exercises the student will be introduced to several types of remote sensing represented by imagery from conventional format: panchromatic, black-and-white infrared, color, and infrared, 35mm aerial photography, thermal infrared, radar, multispectral scanner, and LANDSAT. Upon completion of the exercises the student is expected to know a) the electromagnetic spectrum, its various wavelength sub-sections and their uses as sensors b) the limitations of each sensor, c) the interpretation techniques used for extracting data from the various types of imagery, and d) the cost-effectiveness of Remote Sensing procedures for acquiring and evaluating data of the natural environment.

The laboratory exercises are hands-on experience designed to demonstrate and illustrate principles, techniques, and applications. Actual imagery will be used as practical problems for student solution.

I (a): Remote Sensing Fundamentals
Basic Photo Comparison (Pan/IR)

Selected examples of these exercises follow.

I (b): Extended Photo Comparison (Pan/C/CIR)

II (a): Multispectral - Filters

II (b): Multispectral - Mini Format

II (c): Multispectral - Advanced Equipment

III : Thermal Infrared

IV : Radar

V : LANDSAT

LABORATORY EXERCISES, REMOTE SENSING OF THE ENVIRONMENT

DESCRIPTION OF IMAGERY

I(a). Remote Sensing Fundamentals:
Basic Photo Comparison (Pan/IR)
*OHIO STATE UNIVERISTY, WEST CAMPUS, COLUMBUS, OHIO-JULY 1973-
PANCHROMATIC AND BLACK & WHITE INFRARED.

II(a). Multispectral-Filters:
*NEAR URBANA, CHAMPAIGN COUNTY, OHIO, OCTOBER, 1963-PANCHROMATIC
TRI-X WITH KODAK FILTERS AS SHOWN.

III. Thermal Infrared:
*OHIO STATE UNIVERSITY, NORTH CAMPUS, COLUMBUS, OHIO, WINTER, 1975-
COPY OF THERMAL IMAGE W/PANCHROMATIC FILM.

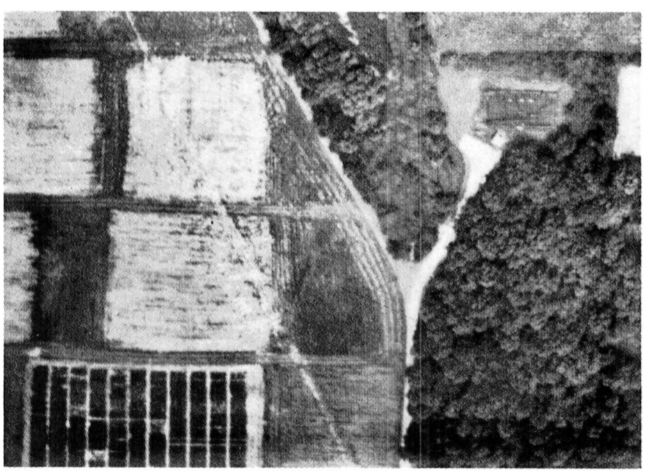
IV. RADAR:
*MERMENTAU RIVER,CAMERON PARRISH, LOUISIANA, JANUARY, 1969-Ka-BAND
HH AND HV RADAR IMAGES-COPY OF RADAR IMAGES W/PANCHROMATIC FILM

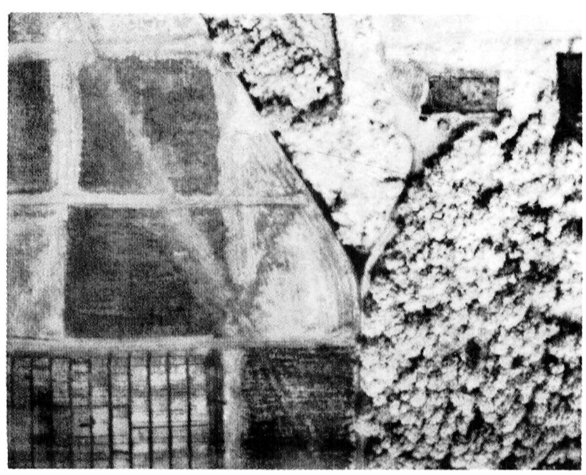
V. LANDSAT:
*PHOTO-ENLARGEMENT OF COLUMBUS, OHIO AREA FROM LANDSAT IMAGE E-1679-
15405, 2 JUN 74, BAND-5.
*PHOTO-ENLARGEMENT OF COLUMBUS, OHIO AREA FROM LANDSAT IMAGE E-1679
15404, 2 JUN 74, BAND-7.
PHOTO-ENLARGEMENT OF COLUMBUS, OHIO AREA FROM LANDSAT IMAGE E-1498-15393,
3 DEC 73, BAND-5.
*PHOTO-ENLARGEMENT OF COLUMBUS, OHIO AREA FROM LANDSAT IMAGE E-1498-15393,
3 DEC 73, BAND-7.

REMOTE SENSING
LAB #1
BASIC & EXTENDED
PHOTO COMPARISON

Laboratory Exercise No. 1 concerns a comparison of (a) panchromatic and black & white infrared films and (b) panchromatic, color, and color infrared films. Each workbook has a "print" representing each film types. The films were exposed in flights over the campus during July 1973.

Object Description	Panchromatic (B & W)	B & W Infrared	Best Sensor
Vegetation:			
Soil:			
Water:			
Culture:			

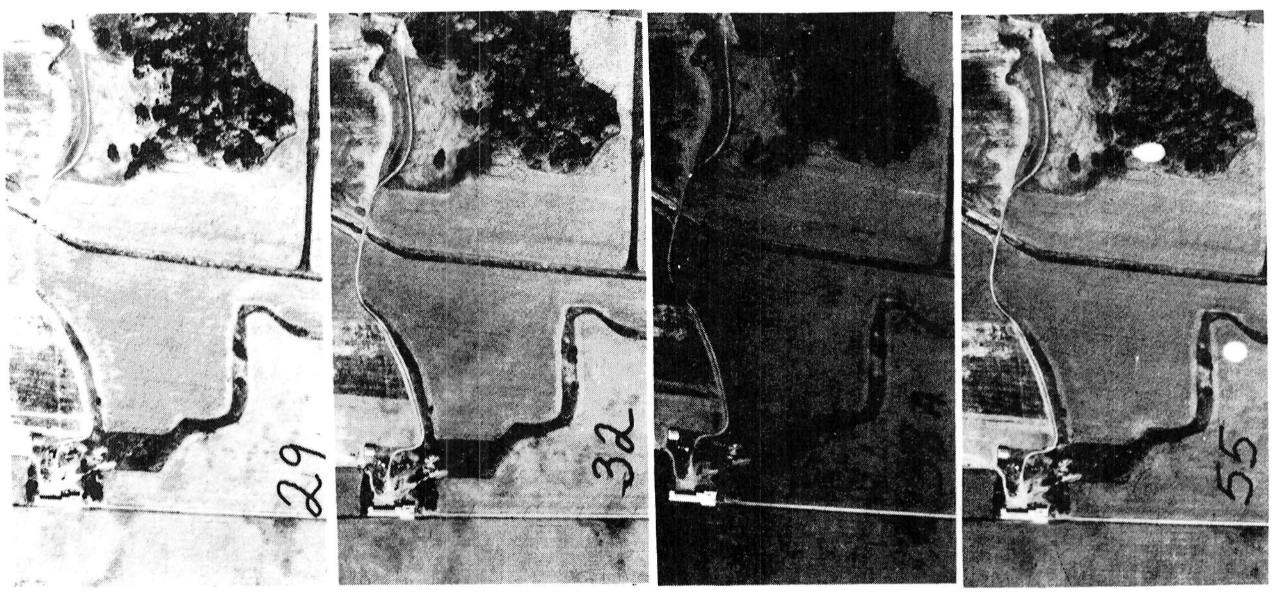




REMOTE SENSING
LAB # 2
MULTISPECTRAL:
FILTERS, MINI-FORMAT

Laboratory Exercise No. 2 concerns a comparison of (a) several B & W photos, each taken with a different filter (thus causing the photos to be reflected data from specific and different parts of the spectrum within the boundaries of visible light); and (b) 35 MM color and color infrared sets of photos.

Filter Number	Filter Color	Object #1 Desc:	Object #2 Desc:	Object #3 Desc:	
29					
32					
38A					
55					
Object Color					
Final Object Identification					



REMOTE SENSING
LAB #3
THERMAL INFRARED

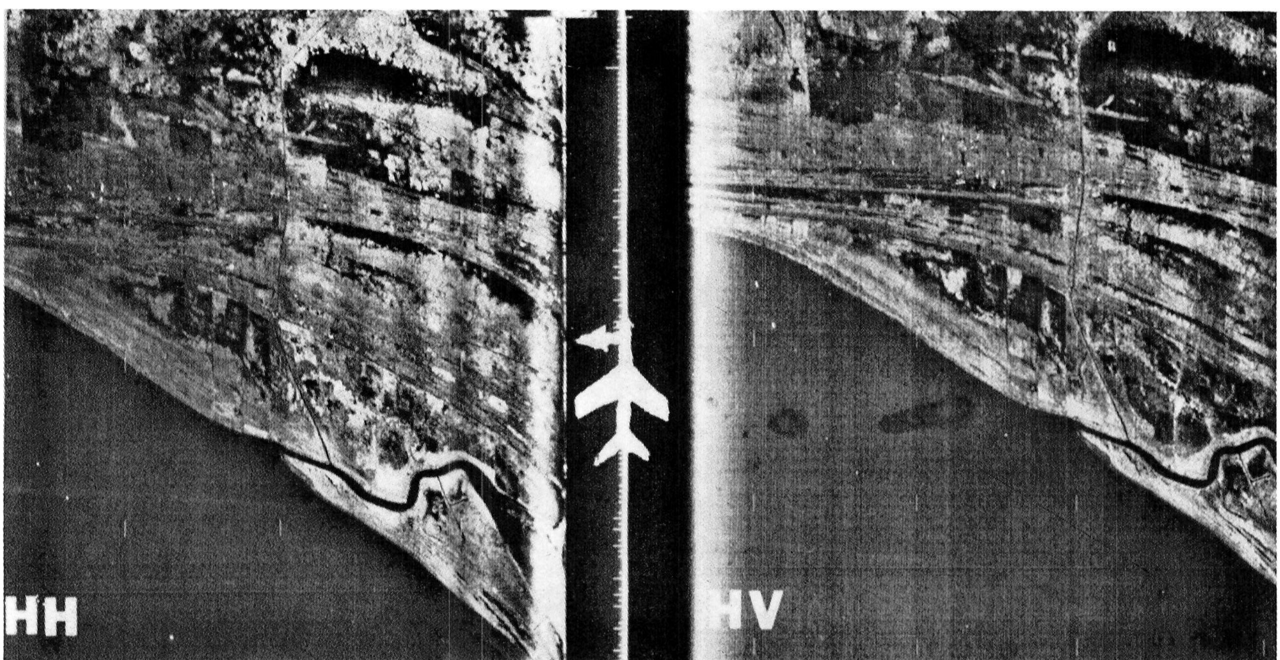
Laboratory Exercise No. 3 concerns the use of TIR data in (a) identifying soil, water, and vegetation surfaces, and (b) determining heat losses from buildings and other objects.

	Tones	Materials & Colors	Heat Loss Severity	Roof Insulation
Object #1:				
Object #2:				
Object #3:				

REMOTE SENSING
LAB #4
RADAR

Laboratory Exercise No. 4 concerns an analysis of (a) radar imagery and (b) a comparison with previous imagery. The image used for (a) is one taken in the Piketon, Ohio area. For (b), the image is a dual HH and HV image taken over the same region as for exercise I (b) and III (a).

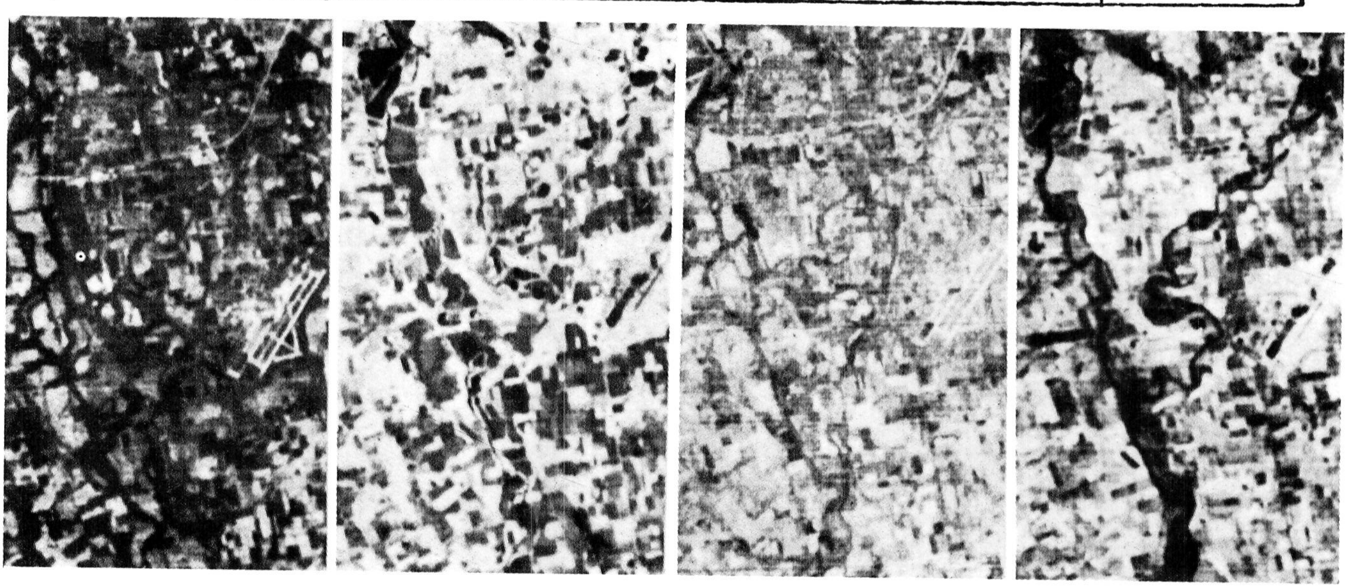
	Tones		Differences	Better Image	Comparison
	HH	HV			
Soil:					
Vegetation:					
Water:					



REMOTE SENSING
LAB #5
LANDSAT

Laboratory Exercise No. 5 concerns the analysis and comparisons of four different LANDSAT images of the Columbus Metropolitan area. These four images consist of: (1) Band 5 summer, (2) Band 7 summer, (3) Band 5 winter, (4) Band 7 winter.

	TONES				
	B 5 Summer	B 7 Summer	B 5 Winter	B 7 Winter	Best Image
Soil:					
Vegetation:					
Water:					
Culture:					



Session 4-A

Agriculture, Forestry, and Range Management

Highlights:

David Lusch presented the only paper during the session, entitled "Diazo Processing of Landsat Imagery: A Low-Cost Instructional Technique." He pointed out that in addition to the low cost of the exposure equipment and diazo film, the diazo processing technique has been a very useful educational and research tool in remote sensing with positive results. Following the presentation, Merle Meyer discussed the importance of sound photo interpretation techniques and how remote sensing training is offered to students at the University of Minnesota College of Forestry. Representatives of several universities listed their remote sensing courses and the departments which offer them. This led to a discussion which strongly suggested that photo interpretation and digital processing need to be taught together, because the two techniques supplement each other. For the closing comments, Marion Baumgardner, the session chairman, asked two questions of the audience: 1) where do we (remote sensing educators) go from here, and 2) what will we want over the next three years. The resulting discussion suggested that possibly ASP, NOAA, and/or NASA provide for future meetings with educational committees being formed to work at problems and distribute results. The session reporter was Doug Knowlton.

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DIAZO PROCESSING OF LANDSAT IMAGERY:

A LOW-COST INSTRUCTIONAL TECHNIQUE

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INTRODUCTION

Of the several methods of color enhancing Landsat imagery, including photographic or photolithographic procedures and additive color viewing, only diazo processing combines the advantages of simplicity, economy and flexibility making it particularly useful in remote sensing education.

Diazo processing of Landsat imagery is based on the simple procedure of contact printing black-and-white positive or negative transparencies onto color diazo film (Malan, 1976). The advantages of using diazotype materials include: 1) the reproduction of positive copies without any intervening negative; 2) the absence of any wet treatment or rinsing of the developed material; 3) the capability of processing under conventional diffuse illumination; and 4) the exceptionally low cost compared to other materials. In addition, the transparent diazo film used in this procedure possesses the valuable characteristic of extremely high resolution (> 1,000 lines/mm) made possible by the virtually grainless molecular structure of the azo dyes which produce the image. Unlike photographic materials, where the emulsion is a dispersion of silver halide crystals (2,000-4,000 Å diameter), the transparent support of diazo film is coated with a true solution which forms a molecularly-dispersed (10-20 Å diameter) photosensitive layer (Dinaburg, 1964).

Photosensitive diazo compounds have absorption spectra which peak in the ultraviolet (365-420 nm). Upon absorption of these actinic wavelengths, these compounds are converted into substances unable to react with couplers to form dyes. Hence, diazo film is positive-working, the density of the dye (color) on the diazo reproduction being proportional to the density (grey tone) of the original.

After exposure to ultraviolet light, the diazo image must be developed by treating it with humid ammonia vapor which provides an alkaline medium in which the undecomposed diazo compound joins with a coupler to create a dye.

EXPOSURE EQUIPMENT OPTIONS

The cheapest exposure method utilizes the sun as the UV illuminant (Seitz, 1977). Even on bright days, however, exposure times will be very long. Obviously, the disadvantages of this procedure are its daylight and fair weather dependence and the variable results due to diurnal and seasonal changes in solar insolation.

A second alternative is to expose the diazo film in a whiteprinter (ordinarily used to reproduce line drawings). These units typically cost over $600 and are not ideal for diazo processing of Landsat imagery. These machines usually contain a central UV fluorescent light source inside of a rotating transparent cylinder. Exposures are varied by changing the speed at which material is transported around the light. Diazo film is relatively slow compared to diazo paper, however, and the slowest transport speed on a whiteprinter is usually too fast, necessitating multiple exposures. As a result of both the curved transport path and the handling of the film between exposure increments, registration between the diazo film and the original image is difficult to maintain.

The best alternative for precise reproduction of Landsat imagery onto diazo film is the use of a contact or vacuum frame which assure stable contact throughout the exposure. A contact exposure unit costing less than $25 can be made by replacing the daylight fluorescent tubes in any light table with ultraviolet lamps (e.g., F20T12/BL) and providing a flat, opaque hold-down lid to cover its surface. Existing vacuum frames can also be used for this purpose by placing a portable light box (fitted with UV bulbs) face down on its surface. Commercially made UV exposure vacuum frames are available for about $850.

Exposure is a function not only of time, but also of illumination intensity. The actinic output of UV fluorescent tubes varies with their age and temperature, as well as with line voltage fluctuations. These variables can be controlled with the use of a light integrator whose probe is filtered to receive only actinic radiation (in this case UV light). In this way, exposure values are based on the amount of illumination, not on the elapsed time. High quality light integrators can be purchased for about $290.

DEVELOPMENT EQUIPMENT OPTIONS

The development of diazo film, using aqua ammonia, can be done in jar or tube developers costing less than $45. These units usually require lengthy development times (although diazo film cannot be overdeveloped) and allow the escape of ammonia fumes during loading and unloading.

Diazo whiteprinters utilizing aqua ammonia can be used but tend to have high operating temperatures and metal rollers in their development chambers which can affect the dimensional stability of the film as well as produce significant scratching. Large, commercial-grade whiteprinters which use anhydrous ammonia work very well for developing diazo film but are expensive ($4,000-$6,000) and require venting to the out-of-doors.

Microfiche developers, on the other hand, are available for about $460, do not require outside venting and provide rapid development without damaging the diazo film by heat or abrasion.

DIAZO MATERIALS

All of the enhancement routines which can be done with diazo processing rely, in one way or another, on the registration of two or more diazo films which, therefore, must be as dimensionally stable as possible. Transparent diazo films are commercially available on either acetate or polyester base material but only the latter has sufficient dimensional stability to warrant use.

Two other important film characteristics to be considered when purchasing diazo film are gamma (γ, a measure of contrast) and maximum density (an indicator of color saturation). An evaluation, conducted at the Center for Remote Sensing, of the three brands of commercially available transparent, polyester-based diazo films indicated that GAF Chromatic Diazo Film was the preferred choice (Lusch, 1980). The specific film types required are 202 PCY (cyan), 302 PMG (magenta) and 502 PYL (yellow), all of which are produced on 8.5" x 11", 3-mil, polyester material. These films, available in 25-sheet packages, cost approximately 40 cents per sheet.

ENHANCEMENT ROUTINES

Diazo processing of Landsat imagery can be a valuable laboratory experience for students of remote sensing. False color composites (FCC's), for instance, can be easily and cheaply constructed by contact printing positive black-and-white transparencies of Landsat bands 4, 5 and 7 onto yellow, magenta and cyan diazo film, respectively. This basic enhancement routine can provide an instructional medium illustrating the concepts of: 1) subtractive color formation, 2) multispectral imaging and image enhancement, and 3) false color formation on color infrared (CIR) film since the bandpass color assignments on CIR film are identical to those used in constructing a diazo Landsat FCC.

If a series of characteristic curves, at varying exposures, are constructed for each diazo film type, the guess work can be eliminated in selecting the most appropriate exposures. Such a procedure also provides the basis for constructing density specified, contrast stretched, false color composites. This routine, which relys on the high contrast nature of diazo film, provides a method of enhancing subtle grey tone differences on each of the three Landsat bands used for an FCC.

Figure 1 shows a characteristic curve, typical of diazo films, produced from a single exposure through a calibrated step tablet containing 21 density levels. Although the form of this curve would remain relatively unchanged, increasing or decreasing the exposure would shift it toward the darker or lighter densities, respectively. Note that diazo film is unable to reproduce all of the grey tones. Input densities less than 1.1, which fell on the toe of the curve, have been compressed into an output density range of only .04-.14. A similar data compression occurs in the shoulder region of the curve where input densities greater than 1.7 are reproduced in the more restricted output range of .96-1.4. Along the straight-line portion of the curve, on the other hand, input densities of 1.1-1.7 ($\Delta D = .6$) have been contrast stretched across an output density range of .14-.96 ($\Delta D = .82$).

Given a series of characteristic curves representing various exposures, the optimum exposure to enhance a given density level D' will be represented by a curve whose straight-line portion is bisected by the input density ordinate D'. For example, the exposure which produced the curve in Figure 1 would be the most appropriate to enhance a density of 1.4 relative to other similar grey tones.

The appropriate exposures for a density specified, contrast stretched FCC can be determined by measuring the densities of a target of interest on the black-and-white transparencies from bands 4, 5 and 7 and plotting these values on characteristic curve sets for yellow, magenta and cyan diazo films.

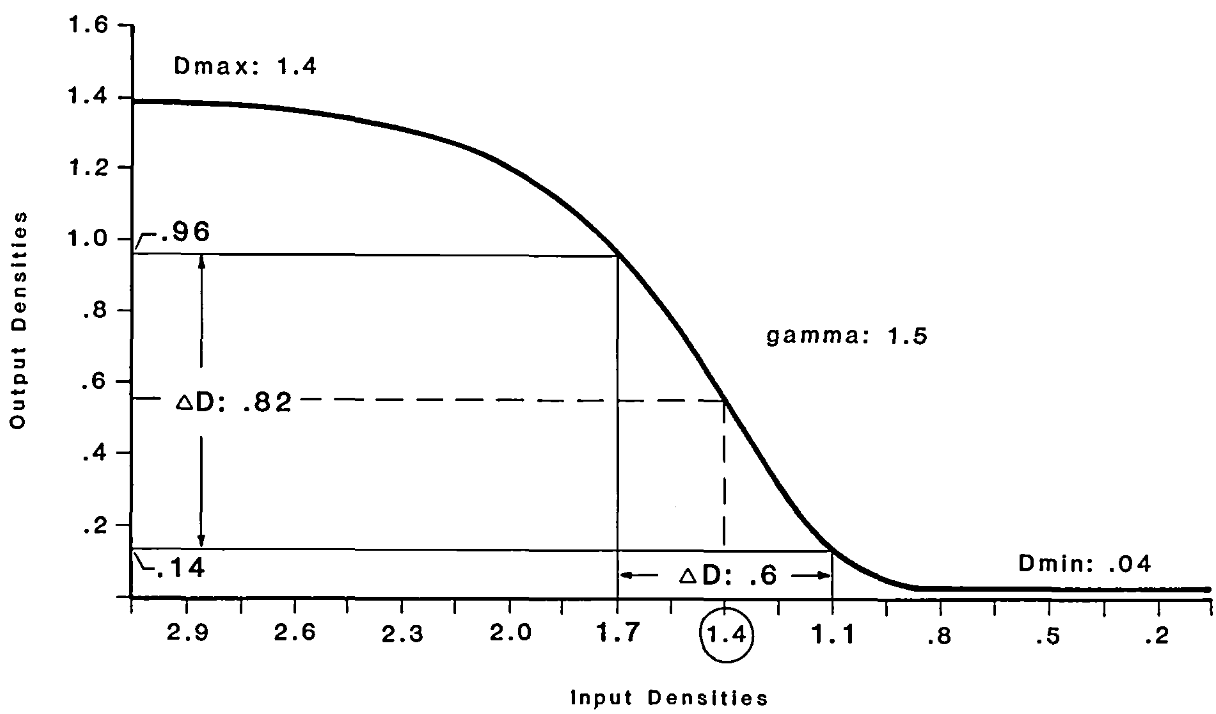

Figure 1. A typical characteristic curve for diazo film illustrating the density specified, contrast stretched enhancement routine.

Up to this point, only the use of positive Landsat transparencies has been discussed. By utilizing negative transparencies as well, two additional enhancement routines are possible. If the positive and negative of any Landsat band are contact printed onto diazo films of the same color and minutely offset when registered together, a type of edge enhancement is achieved. The orientation of the enhanced edges will be determined by the direction of offset. This limitation can be overcome by using a rotating contact frame in which the positive and negative transparencies of the same band are carefully registered together on top of a diazo film. The amount of edge enhancement which results is related to the base thicknesses of the positive and negative films as well as the angle of illumination.

Diazo processing can also be used to produce band-ratio images. This is achieved by contact printing a positive of one band and a negative of another; for instance a 5/7 ratio image is produced by using a positive transparency of band 5 and a negative copy of band 7. Ratio images of this sort are useful because they enhance the differences in spectral reflectivity between the two bands used. A hybrid false color composite can be constructed by using a ratio image in one of the subtractive colors in combination with other ratio images or single bands in the other two colors.

SUMMARY

Diazo processing of Landsat imagery is a relatively simple and extremely cost-effective method of producing enhanced renditions of the visual Landsat products. This technique is capable of producing a variety of image enhancements which have tremendous value in a teaching laboratory environment. Additionally, with the appropriate equipment, applications research which relys on accurate and repeatable results is possible.

In terms of simply providing multiple copies of color enhanced Landsat imagery for use in laboratory exercises, even the more expensive processing equipment could pay for itself within two or three years. Diazo processing should be considered by anyone involved with the visual interpretation of Landsat imagery, whether for research or instructional purposes.

REFERENCES

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Lusch, D.P. 1980. Theory and Practice of Diazo Image Processing. Unpublished Manuscript. Center for Remote Sensing, Michigan State University.

Malan, O.G. 1976. How to use transparent diazo colour film for interpretation of Landsat images. COSPAR Technique Manual Series, Manual No. 6. Pretoria, South Africa: South African Council for Scientific and Industrial Research, 36 pp.

Seitz, J.F. 1977. Producing Diazo Color Composite Images with Inexpensive Equipment. _In_ F. Shahrokhi, ed. Remote Sensing of Earth Resources, v. 5. Tullahoma, Tennessee: The University of Tennessee, Space Institute, pp. 41-46.

Topics Discussed:

List of University Courses

Idaho

FOR 275 API
FOR 300 Field API
FOR 472 Fund. R.S.
FOR 572 Adv. R.S.
FOR 573 Adv. P.I.
CE 319 Photogrammetry
Geog 570 Adv. Cert./R.S.

Kansas

Geog. 426 API
526 API
626 Practicum R.S.
726 R.S. Natural Resources
926 Seminar R.S.
? GIS
Geol 756 Prin. R.S.
CE Photogramm
EE Pattern Recog.
EE Microwave R.S.

Maine

FOR 306 Airphoto Interpretation (Prac.)
FOR 408 Airphoto Interpretation & R.S.
FOR 600 R.S. Seminar
CE 500 R.S. of Environment
CE 200 Intro to Photogrammetry
CE 500 Basic Photogrammetry
CE 502 Advan. Photogrammetry

Mich. State

Geog 224 (API)
Geog 424 (R.S.)

Oregon State

FOR 220 API
FOR 520 Forest Inventory
Geog. P.I.
Geog. R.S.
CE P.I.
CE Photogrammetry (3 courses)
Geol. Photo Geology

University of Southern Mississippi

Geog 411 Photo Interpretation
Geog 412 Remote Sensing
Geog 612 Remote Sensing Seminar
Geog 416 Computer Mapping/GIS

Purdue

CE 557 API
CE 657 Advanced API
CE 500 Introduction Photogrammetry
CE 602 Basic Photogrammetry
CE 603 Advanced Photogrammetry
Geos 500 Photogeology
FOR 291 Introduction Remote Sensing
FOR 557 API
FOR 558 Remote Sensing of Natural Resources
FOR 579 Remote Sensing Seminar
AGRY 545 Inventorying & Monitoring Agronomic Resources
EE 577 Engineering Aspects of Remote Sensing

SUNY - Syracuse

ERE 306 API
FEG 352 Remote Sensing
FEG 363 Photogrammetry I
FEG 464 Photogrammetry II
ERE 570 Remote Sensing
ERE 655 Advanced Remote Sensing
ERE 6 Analytical Phogrammetry
ERE 6 Errors & Adjustments
ERE 7 Intrs. Photogrammetry
ERE 7 Advanced Aerial Photogrammetry

General Discussion

There might be a tendency for departments to create their own courses of remote sensing even if there is a separate discipline of remote sensing. An example given is Statistics.

Remote sensing - there needs to be P.I. and digital processing taught together because they supplement each other.

Where do we go from here? Look to ASP for a central meeting, also NOAA and possibly NASA

Education Committees - to plan and to distribute questions and information for future meetings - what do individuals want at futüre meetings.

What will people want over the next three years?

1. Interaction with peers
2. Use of microprocessors
3. Configurations of academic programs
4. Continue workshops
   - new technology (re-tool)
   - introduce teaching methods of others.
5. Define remote sensing as organized body of knowledge
6. What is at the National Science of remote sensing?
7. Exchange of Education materials (course outlines and materials)

Participants in Discussion on Agriculture, Forestry, and Range Management

AGENS, Kenneth
BAUMGARDNER, Marion F.
BRUNNSCHWEILER, Dieter
BUCKLER, William R.
COKER, Bill
CONANT, Francis
DILIBERTI, Mike
EYTON, J. Ronald
GOODFELLOW, Carolyn
HOFFER, Roger
JOHNSON, Evert W.
LIU, Calvin
LUSCH, David P.
MARTINKO, Edward
MCLAREN, Doug
MEYER, Merle
PAINE, Dave
PHELPS, Richard R.
RIECK, Richard
ULLIMAN, Joseph J.
WILLIAMS, Donald

Session 4b

Engineering and Water Resources

Four papers were presented in this session which was chaired by Ralph Kiefer, University of Wisconsin at Madison. All four papers are printed on the following pages, and notes summarizing the discussion, paper by paper, complete the section. No discussion was generated by the last paper. The session reporter was Tom Hennig, Purdue University.

NASA

CORSE-81

The 1981 Conference On Remote Sensing Education
May 18-22, 1981 Session No. 4B

A REMOTE SENSING CURRICULUM FOR ENGINEERS AND OTHER PROFESSIONALS

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SUMMARY

Cornell University, a pioneer in the development of aerial photographic interpretation, photogrammetry and other facets of remote sensing, has offered formal instruction in these subjects for more than 35 years. Traditionally, emphasis has been placed on engineering applications; yet, the remote sensing area of civil engineering has always attracted undergraduate and graduate students from a range of disciplines, both as registrants in the courses, and as graduate students majoring or minoring at the masters or doctoral level. With the increasing availability of smaller scale, multispectral, and digital data, from aircraft and satellite sensors, course content and the courses themselves have changed substantially.

Cornell's present remote sensing curriculum is designed to provide instruction in three areas: (1) principles of remote sensing, (2) applications of remote sensing in soil and geologic studies, and (3) applications of remote sensing in other environmental studies.

Principles of Remote Sensing

One course on remote sensing fundamental is available for those students who desire a foundation in sensors and, more particularly, in what it is that sensors measure. Physics of remote sensing, electromagnetic sensors, and approaches to data analysis are examined through lecture and laboratory exercises. Various textbooks, journal articles, symposia papers and manufacturers' literature are used to expose students to the best and most current information.

Remote Sensing in Soils and Geologic Studies

Because of the specialized approach and expertise required for extracting subsurface information from aerial photographs, two courses are devoted entirely to landform analysis. In the first course, the keys for landform analysis are presented and used in recognizing and assessing the engineering properties of some 30 geologic landforms. The primary tool is a pocket stereoscope; the primary data are stereoscopic, medium scale, panchromatic aerial photographs; and the primary reference is Cornell's "Land Form Reports," a 600-page manual with 600 hand-mounted photographs. Developed in 1951 for the U.S. Navy, this reference is supplemented with readings from other textbooks, including the manuals of the American Society of Photogrammetry.

In the second course, landform analysis is treated in greater depth and with different types of remotely sensed and supporting data. Emphasis is placed on engineering case studies in different climatic environments. Numerous references are used, especially engineering, soil and geologic reports.

Remote Sensing in Other Environmental Studies

Those environmental disciplines that focus on water or other surface features or phenomena have felt the greatest impact of advances in spectral analysis. In the present curriculum, one course is designed to survey how remote sensing is and can be applied in these disciplines by agriculturalists, environmental engineers, city and regional planners, landscape architects, natural resource scientists, as well as others. The course is oriented toward laboratory exercises and projects, and it draws on various textbooks, articles and reports.

Supplemental Courses

Several other courses are offered to supplement the core courses described above. One course focuses on methods for evaluating environmental factors that affect engineering planning decisions--climate, soil and rock conditions, and water resources. This course makes use of available meteorologic, topographic, geologic and soils information, relegating remotely data to a supportive role.

A series of other courses provides the opportunity for students to undertake research, a project, or study of some specific topic which is not covered in the regular courses. These special courses are offered on demand, normally to graduate students who major in remote sensing.

One additional remote sensing course which has elicited widespread interest at Cornell is a weekly seminar. This seminar brings invited experts from industry, government and other institutions to campus to review current research and applications of remote sensing, with students, staff and other interested individuals.

Future Curriculum Development

Although at least three weeks on digital image analysis is now included in the fundamentals course, there is an increasing need to develop a complete course on this subject. A special topics course on digital analysis was offered once to several graduate students, however, it was felt that the lack of visually interactive digital equipment hindered student appreciation of the full potential of this approach. Acquisition of an interactive facility is being actively planned.

CORSE-81

The 1981 Conference On Remote Sensing Education
May 18-22, 1981 Session No. 4B

UNIVERSITY/INDUSTRY COLLABORATION IN REMOTE SENSING EDUCATION

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INTRODUCTION

The Remote Sensing Systems Laboratory of the University of Maryland supports a graduate level course, "Interpretation of Satellite Imagery for Regional Analysis". During the fall semester of 1980, there were 18 students in the course with baccalaureate degrees in geology, geography, agriculture, transportation, and civil engineering. Fundamental to the course is the concept that the decision-making process in regional land and water resource management can be significantly improved by utilizing the capabilities of computer-based, multi-parameter geographical information systems (GIS). The central thrust of the course is the use of computer-aided interpretation of Landsat imagery as a means for defining the land cover distributions needed for the geographical information systems.

The course assumes that the graduate who becomes involved with remote sensing during the early phases of his or her career will practice in one of two modes of operation, at least for the present. First, he or she may work from an office terminal accessing software in a general purpose computer to obtain outputs from a line printer. In the second mode, his organization could retain a consulting firm to work with him in the definition of land cover data for the GIS. This mode could involve the use of a dedicated interactive color CRT-based system in which he would work with the consulting firm analyst/operator in the classification process. To meet the objectives of the first mode, our students use a version of ASTEP developed by NASA/ERRSAC for the University of Maryland's UNIVAC 1108 system. In order to develop a meaningful experience in the second mode of operation, arrangements were made to use the IMAGE 100 system located in the General Electric Company Digital Image Analysis Laboratory in Beltsville, Md. The collaboration between the University and General Electric provided an excellent opportunity to simulate the client-consultant relationship that a student could encounter in practice.

STUDENT PREPARATION

The use of ASTEP and the IMAGE 100 were not introduced until the last quarter of the course to insure that the experiences would be optimized. The first quarter of the course emphasized the development and structure of multi-level geographical information systems. This phase described the various approaches to data entry and the capabilities of these systems. Students gained practical experience by accessing a GIS set-up on the UNIVAC 1108 that stored land cover, soil type and slope as an array of five second cells for the 1100 sq. km. jurisdiction of Montgomery County, Maryland. They gained an understanding of the power of the GIS by developing line printer maps, preparing statistical summaries and determining the impact of land cover changes on flooding for several drainage basins in real time from a terminal. This first phase was designed to give the students a thorough appreciation of the importance of land cover and the role of the GIS as a management tool in decision making. Figures 1 and 2 are examples of the GIS output.

The second two quarters were devoted to developing an understanding of Landsat as a means for defining the land cover inputs to these information systems. The physical foundations of multi-spectral remote sensing and the various types of sensors were discussed. This phase of the course then examined multi-spectral signatures and the use of computer-aided techniques for their interpretation.

Finally, the fourth quarter of the course was devoted to hands on classification of Landsat digital tapes for the Washington/Central Maryland region. The IMAGE 100 was used first and the ASTEP program, second. No formal classes were held during this phase. The IMAGE 100 was operated at night and the daytime intervals between sessions were devoted to checking ground truth and correcting signatures. The ASTEP approach was conducted as an individual effort by each student with tutorial sessions scheduled to resolve the more difficult problems.

USE OF THE IMAGE 100

The use of the IMAGE 100 was to meet several objectives. First, as discussed earlier, it was to simulate the client-consultant relationship that the students might encounter upon entering practice. A second objective was to develop the land cover data bases that the students required to meet the objectives of their thesis and special topics research projects. In meeting this second objective, the students developed land cover maps for four Maryland counties and the areas surrounding the Baltimore and Washington metropolitan centers.

The role of the General Electric staff was to assume that the teams of students with whom they would be working were well-informed clients requiring a specific project in a pre-defined number of computer hours. The clients had decided that the outputs would be a categorized tape, color positives from a DICOMED film printer, gray scale maps from a line-printer and statistical summaries of the information within each jurisdiction.

The eighteen students involved in the exercise were first broken into two groups of nine, with each group receiving two hours of orientation to the IMAGE 100. The groups were further divided into six teams of three. Each three person team was assigned a county and given four hours of computer time in which to get it done. Before going to GE, each team obtained ground truth and located potential training sites for their respective areas.

At GE, the land cover classification is performed using a data partitioning technique. Although the students had been exposed to the usual classification rules, the course had deliberately omitted this technique in order to force the teams to adjust their pre-conceived approaches, but still meet their objectives within their budgeted four hours. The partitioning technique uses a two-dimensional scatter diagram of the Landsat data by displaying the uncorrelated bands five and seven. This is a highly-interactive, supervised classification method where the decision planes are sequentially inserted into the data space. It allows a very rapid means of analysis in which the analysts divide the space into volumes corresponding to the various land cover types. The color display shows the thematic mapping corresponding to each volume superimposed on the image itself. The results are interpreted and evaluated against available ground truth information. Adjustments are then made where needed until satisfactory classification is produced. Operationally, the advantage of this technique is the ability to change classification decisions quickly and see the results in real time.

As stated above, the first session was devoted to orientation. In the second session, a two-hour period, each three person group worked with a GE operator to produce a rough classification of the appropriate county or metropolitan area. The operator professed no knowledge of the areas involved, but assisted by bringing in his extensive experience with classification efforts throughout the world. At the end of the session, the students were provided with printouts of the classification statistics and binary maps of the county classified. Before the next session one week later, the students reviewed the classifications with respect to available ground truth and developed a set of proposed modifications.

During the third two-hour session, a final classification was developed based on the inputs from the second session and review of the products. At this time, the operator interjected more views and information in order to add consistency to the results of the six groups. It was at this time that the array of smoothing operations available on systems such as the IMAGE 100 were introduced. A Vidicon camera was then used to scan the county and metropolitan area boundaries into a memory plane. The area outside the boundary was eliminated through software manipulation to leave only the classified data inside. Statistical summaries and final gray scale printouts were obtained at the end of this session.

After the students had left, as would be the case in private practice, categorized tapes and photo-products showing the raw Landsat data and the classified themes were developed using a DICOMED film printer. Figures 3 and 4 illustrate these products for Prince Georges County, Maryland.

CONCLUSIONS

The industry/university collaboration was extremely successful and resulted in a high quality course. It gave the students an excellent experience in working in a real-world client/consultant relationship undertaken to accomplish a specific task. It is believed that this type of university/industrial collaboration is going to become increasingly important as private sector high-technology firms continue to develop, while university facilities lag during this period of increasingly severe restrictions on education budgets. Without collaboration with industry, most universities cannot provide their students with meaningful experience on state-of-the art systems.

There are important benefits to the industry as well as the University. First, students are a tremendous source of new ideas. They know basic concepts, but their lack of familiarity with the system leads to questions, that in turn results in the industry making improvements that might otherwise never be considered. In the present exercise, for example, a question as to why the numerical bounds of the signatures were not being displayed on the scattergrams led to new software before the third week that now provides GE's clients with a more convenient access to this additional information. Also, because GE must frequently provide training to a client's personnel, the opportunity to work with a group of graduate students provided their personnel with some excellent experience.

There were two key factors in the success of the collaboration. First, there was a very careful product definition and advance meetings between the University faculty and the company personnel to be involved. Second, the students were not taken into the industrial facility until late in the course, after they had a reasonable knowledge of the physical bases of remote sensing, the concept of spectral signatures, and the fundamentals of pattern analysis.

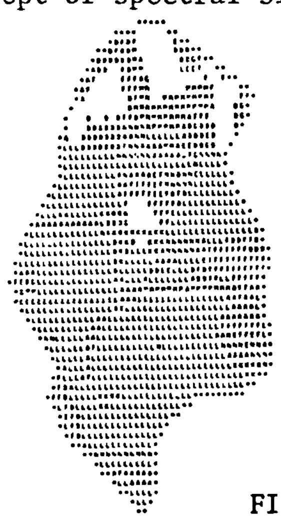
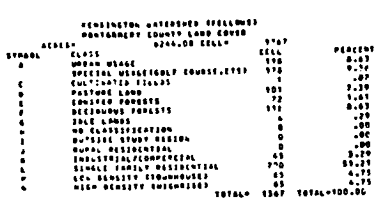


FIG. 1



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                 WATERSHED ANALYSIS PROGRAM
                        (SCS-TR-55)

IDENTIFICATION - IMPACT OF APT/SHOPPING CTR.COMPLEX
                 ON ROCK CREEK TRIBUTARY

RAINFALL INPUT - 100 YEAR/24 HR. STORM = 8.00 INCHES

COMPUTED DRAINAGE AREA - 934.32 ACRES : 1.46 SQ. MI.

        QUANTITY                 PRESENT        PROPOSED

RUNOFF CURVE NUMBER               63.75          68.84
TIME OF CONCENTRATION(HRS.)       1.93           1.78
VOLUME OF RUNOFF(IN.)             3.76           4.34
PEAK DISCHARGE(CFS)               1070           1330

               ************************
     NET CHANGE IN RUNOFF VOLUME = 0.58 INCHES - 15%
     NET CHANGE IN PEAK DISCHARGE = 260 CFS    - 24%
               :**********************:
```

FIG. 2

FIGURES 1 and 2
EXAMPLES OF UNIVERSITY
GIS OUTPUTS

FIGURE 3

CRT DISPLAY OF LANDSAT IMAGE
OF WASHINGTON, D.C. REGION
WITH PRINCE GEORGES COUNTY
BOUNDARY

(Reproduced from original Color image)

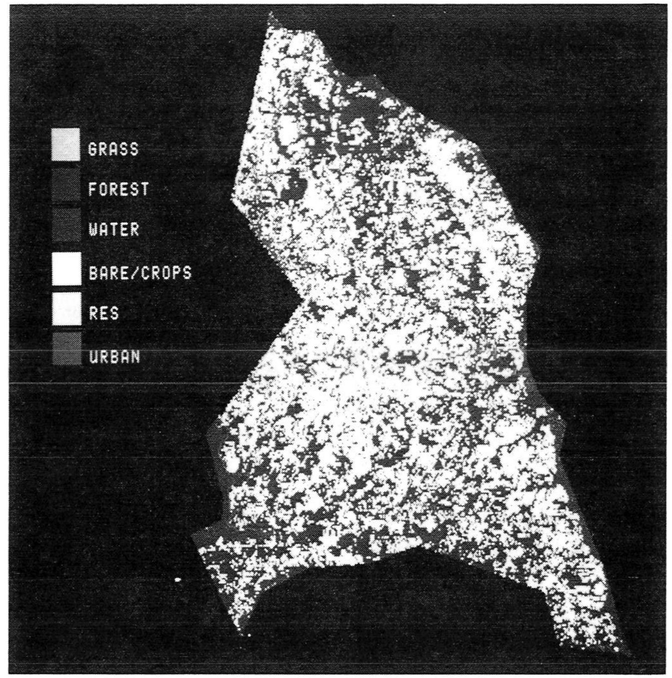

FIGURE 4

LAND COVER DISTRIBUTIONS
OF PRINCE GEORGES COUNTY MARYLAND

(Reproduced from original Color image)

NASA

CORSE-81

The 1981 Conference On Remote Sensing Education
May 18-22, 1981 Session No. 4B

EXPERIENCES IN PRESENTING REMOTE SENSING SHORT COURSES IN THE TRANSPORTATION FIELDS

by

Dr. Harold T. Rib 1/

INTRODUCTION

Most of my experience over the past 22 years has been concerned with remote sensing applications and training in the transportation field, primarily as applied to highways. For example, during the past 10 years alone, I have participated in 35 short courses of 1- to 3-week duration, taught 14 semester courses, participated in and coordinated over a 2-million dollar research program, and participated in 4 engineering projects in which remote sensing was partly or totally involved. The comments in this presentation are based on my observations noted from these varieties of experiences. Although they are concerned with the transportation field, they are equally applicable to many other disciplines.

Remote sensing techniques can provide useful and cost-effective data in all aspects of the transportation field from the initial planning stages, through the stages of location, design, construction and maintenance; however, its actual application is not necessarily assured unless a qualified interpreter is available to do the work and management has accepted its use. These are two key elements in the use of remote sensing techniques. It is

1/ Visiting Professor, University of Maryland; Chief, Aerial Surveys Branch, Federal Highway Administration.

important to note that remote sensing is one of several tools that can be used to obtain and analyze data, and although it is cost-effective, it would not be used if qualified interpreters are not available to perform the work. Equally of importance is the acceptance of this technique by management. There have been too many examples of organizations not using remote sensing techniques in their work even though qualified interpreters were available on their staff. But assuming these techniques have been accepted by management--which is the case in most highway organizations--then the key to its application is qualified interpreters.

INTERPRETERS--KEY ELEMENT

The interpretation of remote sensing data is largely an "art." Although the production of the images on remote sensing data is based on scientific principles and results of laws of nature, the resulting images are a product of numerous interrelating factors. The "art" is the ability of the interpreter to decipher which of the many interrelating factors most influenced the resultant image so that useful information can be extracted. Let's use for example the case of bullrushes which grow in wet areas. On an aerial photograph, a field of bullrushes may appear as a fairly uniform medium gray area of vegetation with no indication of any water present. If the interpreter is able to determine that the vegetation in the scene is bullrushes and is also knowledgeable about the environment of bullrushes, then the interpreter could deduce that the area has a high water table even though no water is discernible on the photograph. The "art" of interpretation, then, is a function of the ability of the interpreter--and in a manner similar to the field of art, just taking art courses doesn't make the person a Picasso--the interpreter's abilities are a result of training, aptitudes, background, and experience. Then, where and how do we obtain the all-important "interpreters"?

The majority of interpreters are developed in one of three ways: (1) by specialization through concentrated studies on basic principles, techniques and applications; (2) taught it as one of the tools used in performance of work in various disciplines, e.g. engineering, geology, forestry; or (3) by on-the-job training in their professions. Developing specialists in a field takes years of concentrated study plus many more years of practical experience. It is a long process and provides too few practitioners to meet the needs. It does, however, provide the leaders, innovators and teachers. The greatest number of interpreters are provided by the latter two methods. Those trained in particular professions learn to apply remote sensing techniques as one of the tools of their trade, either in school when they are learning their profession, or on-the-job when they are out practicing their profession.

Unfortunately, in the engineering field as well as in many other fields, few engineering students receive any training in remote sensing in their undergraduate curriculum. This training is left for graduate courses, where again, it is not required for all graduate students. Thus the total needs are not being filled by our colleges and universities in their normal program. Likewise, there are too few qualified interpreters out in the professions to provide the on-the-job training to meet all the needs. For these reasons, short courses have been developed in various professions as a means of fulfilling the need for interpreters.

SHORT COURSES

A short course is not a panacea for quickly providing trained interpreters, but it is a very effective way of introducing a new technique or approach to the practicing professional. Under the proper circumstances, it is almost as good as on-the-job training. Realizing that the ability of people to obtain information from remote sensing data is based on their training, background and experience, the most successful approach for a short course is having participants with background and experience in the subject area. By providing the training in the use of remote sensing techniques in the participants' area of concern, it is much easier for them to grasp the significance of this new tool to their work and thus can more quickly apply this new tool. On the other hand, the short course is not an adequate substitute for the normal semester-type college courses for students or recent graduates with little or no experience in their profession. It is too short a time frame for them to grasp the techniques and the concepts of applications in their particular field. Lastly, it should be recognized that remote sensing techniques can be applied to such a variety of disciplines and large scope of activities within each discipline, that to be effective, the short course has to be definitive in scope. One can't cover the whole waterfront in one course.

Scope and Length: I have presented mainly two types of short courses in the past 10 years: one a general aerial surveys course for highway personnel covering the full range of highway applications; the other a remote sensing course for geotechnical and environmental personnel. The aerial surveys course covers the principles and applications of photogrammetry and remote sensing, while the remote sensing course is concerned just with the principles and applications of remote sensing. The ideal length for the aerial surveys course is three weeks--one week photogrammetry, one week remote sensing, and one week of applications including a field problem. The ideal length for the remote sensing course is two weeks--one week principles and techniques of remote sensing, and one week of applications including a field problem. Practical considerations, however, have limited both courses to two weeks since most organizations could not spare their people for more time than that. In a few cases, at the insistence of the sponsoring organization, only a one-week remote sensing course was presented. This was not very effective because an important part of the course, the applications and field problem, was omitted.

Some short courses have been presented at the headquarters facility in Washington, D.C., but the majority are held at the facility of the hosting States. The courses held in the States have been the most successful by far. A State wishing to have a large number of its staff trained can accomplish this if the course is held at its facilities. If they have to send people out-of-State, they are limited to sending one or two persons, and many times the out-of-State travel requires the Governor's approval. Additionally, when the course is held at a State facility, the course is adapted for conditions and problems in that State. For example, a course held in Virginia would not cover the airphoto patterns and problems of the glacial landforms of the northern States or the desert problems of the western States. Also, the photography and imagery used in the course is from the local States whenever possible. This makes it easier for the participants to relate the remote sensing data with the ground conditions they are familiar with. All of the above advantages are not obtained when a short course is held at a central location like the headquarters office in Washington or at a university facility. At these courses the breadth of coverage has to be greater in order to encompass the various areas of the participants, making it much harder for them to relate the remote sensing data from the course to ground conditions they are most familiar with.

Format: Figure 1 shows a master schedule for a recent 2-week remote sensing short course. It is typical for this type of course, but each course is individually tailored to the particular State's conditions and problems. The course generally emphasizes methodology and applications. The first 1 1/2 days are spent on remote sensing principles and techniques. During the next 3 days, half of each day is spent on methodology for measuring on photographs, and the other half of each day is spent on the techniques for the interpretation of photography and imagery. This half-day split of dissimilar topics was suggested by the participants several years ago and it works very well. Attempts are made wherever possible to alternate the lecture and laboratory sessions so as to maintain a high level of participation by the attendees. The second week concentrates on applications of the techniques described the first week. The major facet of the second week is the field problem where the methods discussed in the course are applied on actual problems of importance to the host State such as route location, environmental analysis, and materials location.

Field Problem: Inclusion of the field problem is one of the most important factors in the success achieved in these short courses. The material covered the first week of a short course is essentially that covered in a typical one-semester remote sensing-interpretation graduate course with one major exception--there is not an equivalent amount of laboratory time in the short course. Although materials are available for study in the evenings, after 8 hours of concentrated work, only the most dedicated participants take advantage of this. Thus the student has little time to digest all the material and think about it as in a normal college course. The field problem fills this as well as several other important rolls. It provides the participant with an opportunity to (1) review the principles and techniques and try to apply them on an actual highway problem; (2) compare these techniques to the ones usually used and note the advantages and limitations; (3) gain confidence in using the new tool by performing the analyses and checking the results directly in the field; and (4) clearly demonstrate the type and amount of information provided by this tool. An additional benefit to the participants is that they learn to appreciate a multidisciplinary approach to solving the problems since the teams are composed of 3 to 4 participants with different backgrounds--e.g. a geologist, soils engineer, environmentalist, and photogrammetrist.

CONCLUSIONS

The following comments list in summary form some of the advantages and limitations of short courses I have observed during the years of experience in presenting them. They specifically apply to the transportation field, but many of them are equally applicable to other fields.

MASTER SCHEDULE ST. PAUL, MINNESOTA TERRAIN INVESTIGATIONS USING REMOTE SENSING TECHNIQUES March 17-28, 1980

HOURS	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
8-12 a.m.	—(Start 10 a.m.) — Opening Introduction Aerial Surveys—Highways Interface	Availability of Photography & Imagery Interpretation Techniques & Laboratory Photographic Characteristics & Laboratory	Measuring Elevation Differences Laboratory	Laboratory (Cont.) Review of Assignment Measuring Horizontal Distances Route on Uniform Grade Laboratory	Laboratory (Cont.) Depicting Route Stereoscopically Laboratory
	L U N C H	L U N C H	L U N C H	L U N C H	L U N C H
1-5 p.m.	Remote Sensing Principles and Parameters Stereoscopy Laboratory Types of Photographs	Pattern Analysis Landforms of State Alluvial Landforms Floodplains & Terraces	Alluvial Landforms Fans & Deltas Aeolian Landforms Laboratory Glacial Landforms	Laboratory Sedimentary Landforms Igneous Landforms Metamorphic Landforms Laboratory	Review of Assignment Interpretation of Imagery Imagery Laboratory
	S E C O N D W E E K			S E C O N D W E E K	
8-12 a.m.	Procedures for Performing Remote Sensing Projects Techniques for Evaluating Multiple Factors Laboratory: Application Problem	Areas of Application (Cont.) Laboratory: Application Problem	F I E L D	F I E L D	Review of Field Problem Summary Critique (End)
		L U N C H	L U N C H	L U N C H	L U N C H
1-5 p.m.	Overview—Areas of Application Laboratory: Application Problem	F I E L D P R O B L E M	P R O B L E M	P R O B L E M	

Figure 1. Typical 2-week Remote Sensing Short Course.

Advantages:

1. Can indoctrinate experienced personnel in the use of remote sensing techniques as an added tool in performing their work. There have been many examples where the participants took the results of the field problems and applied them directly on their projects. Many others start to use the data in their work shortly after the course. In almost every case, there is an increased demand for remote sensing data within the State organization following the short course.

2. Can lead to development of remote sensing experts. As the participants gain experience in using remote sensing techniques, they apply it to broader areas of work. In some States special sections have been organized to provide this service for other parts of the organization.

3. It is the fastest way to train interpreters. This is true only if the participants already have the proper background and some experience in the topic area of the short course. It does not apply equally to inexperienced persons. For inexperienced persons it provides them with an understanding of the methodology and areas of application. They need added experience before they feel confident in applying it in their work.

4. Most successful short courses are those presented at the host's facility. This enables more people from one organization to be trained at one time than if everyone had to travel to a central facility. Also makes it possible to concentrate on the problems of greatest concern to the State in an area they are most familiar with.

Limitations:

1. Time. There never seems to be enough time in a short course to include everything the instructors wish to cover or to allow the students to review and apply the techniques. A short course is usually a compromise of conflicting demands: the amount of time the participants can stay vs. the time needed to accomplish the task. In all of the courses I have presented I have never had a comment that it was too long. The usual comment is that it should have been longer.

2. For most participants it is an indoctrination. In most short courses the participants have a broad range of backgrounds and experience. I have had anywhere from draftsmen and technicians to Ph.D's with years of experience attend the short courses. Every participant gets some value out of the course, but only those with the proper background and experience can directly apply the tool. The others have to gain more experience before they can adequately apply the techniques.

3. Cannot cover all possible applications in one short course, need to concentrate on limited number. With a broad range of participants, everyone's needs cannot be accommodated. Time does not permit. However, a variety of field problems can be developed to cover several different applications.

CORSE-81

The 1981 Conference On Remote Sensing Education
May 18-22, 1981 Session No. 4-B

FEDERAL AND STATE SHORT COURSES OFFERED BY RSIP AT LOUISIANA STATE UNIVERSITY

J. M. Hill
Civil Engineering Department
Louisiana State University
Baton Rouge, LA 70803

The Remote Sensing and Image Processing Laboratory (RSIP), Louisiana State University, Division of Engineering Research is barely two years old and has, therefore, had to rapidly establish a professional reputation in order to generate applied and basic research programs. The applied research program has been successful because of our work in the area of short courses and regular courses offered over the academic year. These courses must be well thought out, organized, and conducted with the user in mind. They generally take six months to one year to realize any return (i.e., in the form of contracts).

When a research center is new and has time on its hands it is best to generate a color brochure to emphasize at least your potential. We, therefore, generated a brochure that had great visual impact. These brochures have already begun to help generate projects, but again they must be done well and in color. Do not get cheap with the only initial product a potential funding agency will take back to his office!

Our first short course was funded by the Corps of Engineers on a national basis. While we have a full time staff of about seven people (4 faculty members), we had not yet worked together, much less with faculty from around the campus. The first short course turned out to be a very unifying experience in that 1) 4 to 5 very active "remote sensing" faculty members from other departments participated, 2) researchers from neighboring federal centers participicted (i.e., Waterways Experiment Station, EROS/Bay St. Louis, MS), and 3) lab materials for the first remote sensing course in the Civil Engineering Department were established. A strong multidiscipline program was established for we found experts in the following areas; radar, sonar, pattern and texture recognition, image processing, photogrammetry, data base management, atmospheric physics, and a variety of applications.

The difficult task with the Corps short courses was to attempt to service a variety of user needs (i.e., looking for geologic faults or counting ducks in a lake). A questionnaire was sent out before each course to determine the interests of each participant. The goal was to attempt to tailor the hands on course materials to their needs. We found that variety was the key to success. Variety took the form of 1) alternating instructors with varied backgrounds and teaching techniques, 2) hands-on labs limited to 2.5 hours each, 3) presentations from Corps personnel that were already actually applying remote sensing to solve Corps problems, 4) a morning field trip to different land-use/ecological areas with film of varying spatial resolutions (i.e., TIROS, Landsat, U-2, aircraft) and spectral bands (color infrared, B/W, color), 5) laboratories with 12 or less people to allow for individual instruction (this was critical in a dark room in front of an interactive CRT system), 6) a teaching material/ lecture course flow from photographs to an interactive color CRT developed confidence in the multispectral digital approach (especially for those who had never seen such a system), and 7) maybe most importantly an "ice breaker" social event on the first night was essential to acquaint the participant with the instructors.

The experience gained in these courses led to courses for state personnel. The best technique was to first have a management level (particularly easy since we are in the state capital) short course. This became an overview course of from one to four hours where only economics (cost benefits), data acquisition, applications, end products, and other management level decisions were discussed. Managers within such departments as the Office of Public Works, Department of Natural Resources, and the Department of Transportation and Development then returned to their offices and recommended that their operational management/working level personnel attend a more applied type of demonstration. We then take role of the participants, and ask that they put in writing the benefits of using our system in their programs. These are to be returned to their boss within one week. The response is usually great and we then establish a short course (sometimes mornings, sometimes evenings) with emphasis on the area of interest of a particular agency or department.

Since this is a relatively new technology, it is also wise to get young influential state agency personnel to take formal remote sensing courses. The State usually pays for the course and it instills confidence and a basic working knowledge of our capabilities as well as areas that need further development. Funded projects have come from every state participant in my classes over the past 3 years. On the other hand it puts pressure on the teacher to produce, but it keeps you honest and it is well worth it in the long run.

Short courses, while sometimes looked upon by the University administration as "nonproductive" (unpublishable) activities pay off in at least four ways and these are as follows:

1) Reputation with state or federal users
2) A working level team spirit among faculty and staff
3) Eventual larger funded research projects
4) A wealth of lab materials that can be used in your academic courses.

We have been extremely diverse in our research probably for two reasons 1) because the needs are there and they are challenging and 2) we need the funds to keep the "system" working and maintained. Our projects have ranged from equipment grants from NSF, to DMA and AFOSR pattern and texture grants, to Corps vegetation mapping in Arkansas with aerial photographs, to USGS Landsat derived water type and useage in irrigated rice fields, to such state projects as using Landsat to map soil/forest habitats of the entire State, characterization of hazardous waste sites, and various aspects of coastal zone management.

After about one year the computer was fully operational and we had installed NASA/ERL's (Bay St. Louis, MS) ELAS software. Our Interdata 8/32 computer is the same as ERL's and we can, therefore, update our system as NASA progresses. This system can also eventually handle Landsat-D data. We found it important to keep up with NASA, but even more importantly we have implemented alot of new software (developed by us and other agencies) and at present we are processing data types such as Landsat, TIROS, NIMBUS-G (Ocean Color Scanner), NOAA, aircraft MSS and radar, and digitized aerial photographs and medical images (i.e., x-rays).

It is critical to develop a photointerpretation facility maybe even before (or at least at the same time) the computer system is being implemented. The minimum facility should include light tables, stereo viewers, a Kargl projector, and even a zoom transfer scope. A set of up-to-date aerial photographs and maps of the entire state is also one of the best investments any lab can make. It will create visibility as a data source and within itself generate new projects.

While our satellite capability was going well, the Mexican ITOX oil spill occurred (possibly threatening coastal resources) and we had recently missed a spring flood because of cloud cover and no real-time data acquisition capability. The Louisiana Office of Coastal Zone Management (DNR) gave us a $700,000 grant to acquire a 12 channel Daedalus MSS system (with associated computer peripherals) to be mounted on surplused twin engine NASA Beechcraft. The plane is equipped with a passive microwave system (for soil moisture studies), 3 Hasselblads, a black and white mapping camera, video viewfinders, and numerous atmospheric monitors. We anticipate an operational system by September 1981.

While our system is developing at a rapid rate, I feel that mention should be made of difficulties encountered along the way. These areas are as follows, 1) an effective interdisciplinary management plan still needs development, 2) on-line operational funding is needed to maintain the system, and 3) more applied faculty members from other departments are needed, but are not available.

Academic courses at LSU have historically included cultural and physical aerial photointerpretation courses and an overview Remote Sensing of the Environment course in Geography. As of recent, Civil Engineering has developed a photogrammetry, an Application of Remote Sensing to Civil Engineering, and a graduate level Remote Sensing in Engineering Research course. The Electrical Engineering Department offers the following remote sensing related courses; Image Analysis 1 and 2, Pattern Recognition, and Signal Processing. Very few EE or CE students, however, at present take these courses when offered outside of their own departments.

This is a brief outline of what I feel to be a new remote sensing oriented academic/research program that has developed a strong foundation. Our track record to date is good and I welcome anyone who is trying to develop a similar system to both follow our future developments and contact me if you have any questions.

Discussion following W. Philipson's presentation:

Utilizes several texts in basic remote sensing course. Copies are made available on reserve in library. Occasionally parts of texts are Xeroxed and provided the students.

Does the fundamentals course use Landsat imagery? No, based entirely on airphotos

"Remote Sensing: Environmental Applications" course, what do you cover on environmental quality? Land uses and air quality.

How do you approach digital remote sensing? With digital aspect, we utilize main frame for processing of Landsat CCT's. Are acquiring an interactive system through a grant.

Class admission? If student can meet the prerequisites, he is allowed regardless of class standing. Elective courses generally chosen from land forms, remote sensing or surveying by Civil Engineering students.

Support for Grad Students? CE still not bad, but Remote Sensing funding getting scarce - mainly NASA.

Is your program a separate laboratory or is it within the usual department structure? Regular department structure.

Do other departments offer Remote Sensing? One other department offers a course.

Do Remote Sensing grad students interact with EE on pattern recognition and digital image processing? No - very little interaction by faculty or students. Work mainly with Natural Resources and Geology students as minors.

Discussion following paper by R. Ragan

Pattern Recognition at University of Maryland taught under CS Department rather than EE Department.

Task Force had following nature:

Modifying previous hydrology models developed by Soil Conservation Service, Corps of Engineers, etc.

Utilized to expose CE students to use of Remote Sensing

25 students involved

Based on Landsat & U-2 imagery

Data base available containing imagery, digital data, soil map data, etc. on 5-sec. cells.

Computer Science - How much do Remote Sensing students get? Masters students usually only get 1 CS course - preferably Digital Image Processing. Ph.D. students often minor in CS.

What system is being acquired? System being procured will be stand alone, tied to PDP 11/45. Will be located in CS department for them to support. Vendor has not been selected for the procurement yet.

Have you any information on data base overlay accuracy? Being investigated by Ph.D. thesis now. Projections used are a problem in the data sources.

How did you arrange use of the GE Image 100? Time used at GE facility was paid for at educational rates through a contract.

What image sizes do the students use? Students given full Landsat scene to find their area which were usually less than 512x512.

Discussion following H. Rib's presentation:

Can course be developed around a digital approach? Yes, Purdue does this via phone hookups from field locations. Highway departments are some of the most advanced photogrammetry shops in U.S.

Have you been to states with own planes where they get coverage but don't really know what they have? Yes, I emphasize use of color photography. Tell them patterns for finding materials for road construction. Often departments are using photos for only a few of the potential uses that they can be, or not at all.

How do you get photos for areas? I order new coverage in areas where no coverage exists.

What do you charge? There is no charge, we provide photos, stereoscopes, etc. User must only supply room, projectors, etc.

After Minnesota short course, there has been a follow up using photo interpret you taught to determine if crop losses being blamed on highway department were legitimate or not.

Participants in Discussion on
Engineering & Water Resources

Barnett, Albert P.
Burton, Vinston, Jr.
Hennig, Thomas A.
Hill, John M.
Kiefer, Ralph W.
Lillesand, Thomas M.
Miles, Robert D.
Mintzer, Olin
Pardee, Tom
Philipson, Warren R.
Ragan, Robert M.
Rib, Harold T.
Rios, Julio C.
Smith, William Freeman, Jr.
Soehngen, Henry F.
Song, Cheng-Jyi
Whiteford, Gary
Wilson, Len
Woods, Edmund

Session 4-C

Geography

Highlights:

A room full of geographers (and then some) contributed to a spirited session chaired by Jack Estes, University of California at Santa Barbara. The reporter for the session was Ellen Dean, Purdue University. In all, six papers were presented, all summarized in the following pages.

Summary comments for the session included the following observations:

The geographic user community is lagging behind in use of existing remote sensing techniques due, in part, to inadequate technology transfer.

Geographers are having problems obtaining funding for remote sensing research because they are competing with other disciplines and organizations that are "up" on the current technology.

Some technology transfer programs are "an affront to our intelligence" -- both too expensive and too simplistic.

We geographers have remained relatively passive, and yet if we don't maintain our technological skills and credibility as scientists, we will lose our position in the remote sensing field, specifically lose out on funding.

We are getting bogged down in techniques while the international market is charging ahead (e.g., SPOT). Landsat and even TM will soon be obsolete.

Geography is growing in the remote sensing field; we have a lot to offer, but need to "jump in."

NASA

CORSE-81

The 1981 Conference On Remote Sensing Education
May 18-22, 1981 Session No. 4C

THE LOCATION AND SCOPE OF GEOGRAPHIC REMOTE SENSING TRAINING IN THE UNITED STATES

Dr. Arthur J. Hawley

University of North Carolina at Chapel Hill

The accompanying maps display the distribution of graduate departments of geography in the United States and enrollments in remote sensing courses in all geography departments during the past two calendar years. It was anticipated that the two distributions would show a marked similarity since remote sensing is a relatively new geographic tool requiring specialized training to use as well as equipment not normally found in most geography departments. Thus only the larger graduate departments can "afford" to devote time and resources to this specialty. Moreover, it was anticipated that this rather narrow specialty would be most highly correlated with the largest graduate departments since they can afford to support specialists more easily than smaller departments who must teach a variety of courses in order to support a viable program.

Data for the map on graduate departments of geography were obtained from the Guide to Graduate Departments of Geography in the United States and Canada 1980-81 published by the Association of American Geographers in September of each year. A check of the previous year's guide revealed only two new departments (University of Massachusetts at Amherst and Southern Connecticut State College) and only one deletion (Western Carolina University). Faculty members listed were counted to obtain the size of each department. Part-time faculty were counted as one-half a full-time faculty member. Professors emeritus were included as faculty if topical specialties were included after their name indicating that they were still teaching. The three categories of department size correspond to what seem to be natural breaks in the data. Data on remote sensing courses and enrollments were obtained from the 1980 and 1981 Schwendeman's Directory of College Geography of the United States. This annual publication lists courses, enrollments, faculty, activities and publications by department. Unfortunately, I know of no comparable listing for Canada so it was decided to limit the study to the United States. A course in remote sensing was counted if that descriptive title appeared alone or in combination with another term. Each of the above distributions was plotted on an outline map.

A broad correspondence does exist between the graduate departments of geography and the courses in remote sensing. However, the correlation is far from complete and the exceptions are frequent and large enough to cast doubt upon the accuracy of the original hypothesis. Whereas many large departments do offer courses in remote sensing, many smaller colleges and universities do also. A number of possible explanations can be offered for the discrepancies: 1) course titles, 2) the liberal arts orientation of geography departments in many universities, 3) job-oriented skills which many smaller departments have emphasized, and 4) in the tight job market many new graduates of even the larger departments have had to accept positions in smaller departments and colleges.

One unavoidable flaw in this research has been relying upon the course title to identify a course in remote sensing. Much further digging will be necessary to determine if the course in question is substantively different from last year's air photo interpretation course. In some cases it appears that the change has been cosmetic to keep up with the latest terminology. A course description and outline would be needed to resolve the matter.

Traditionally geography has occupied a service role in many if not most university curricula. Job-oriented skills were taught but only as tools to probe the questions of social or physical scientists. Obtaining an education was the focus of university geography training as it was in the other sciences. More recently quantitative methods and computerized data sets have occupied much of the attention of geographers at the graduate level. This neglect of technical courses can help explain the striking absence of remote sensing (at least by that name) from the course listings of many major universities.

While major university geography departments have been slow to respond to the technical skill offered by remote sensing, many smaller colleges and community colleges have been market-oriented. As job listings for specialists in remote sensing increased, the number of smaller departments having such courses has increased dramatically. This skill is in demand and these schools have been responsive to the opportunities present in the new, highly competitive marketplace. Since many of these schools are both newer and have smaller administrative staffs, they have overcome the cultural inertia of traditional curricula much more rapidly.

Finally, it is interesting to speculate on the ramifications of the tightening job market for graduates of even the larger universities. It would not be surprising if they carried their technical expertise from their graduate training into the smaller departments where they found jobs upon graduation. The proliferation of remote sensing courses may reflect this diffusion but much more detailed study will be needed to either substantiate or reject this hypothesis.

Maps of remote sensing courses in both 1979 and 1980 have been included since many schools which had a course in one year did not the next. This may reflect real growth in the field of remote sensing in geography when a new course was offered in 1980. However, a word of caution is appropriate. Many departments do not report their course offerings every year in the directory. Several of the courses were repeated listings from the previous year. Also departments with remote sensing courses offered every other year would mysteriously disappear from the listing on those alternate years. It is not possible to determine from the data whether courses offered in 1979 but not in 1980 are still alive and well or whether they have been eliminated. Under a more mobile job market it was not unusual for a course put in to match the interests and specialties of a new faculty member to die a quiet lingering death when that faculty member moved to another institution. How viable existing remote sensing courses are remains to be seen.

SOURCES

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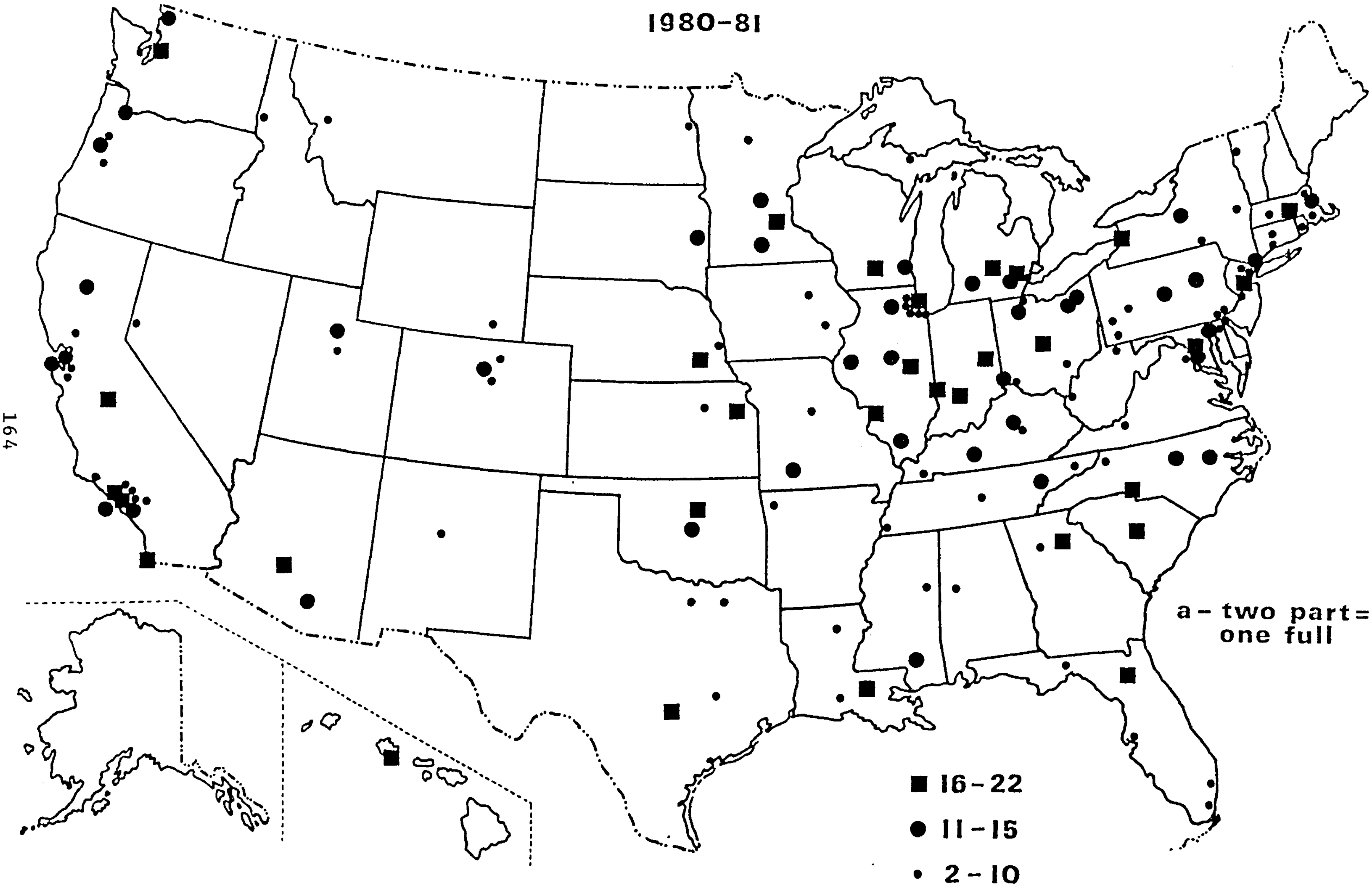
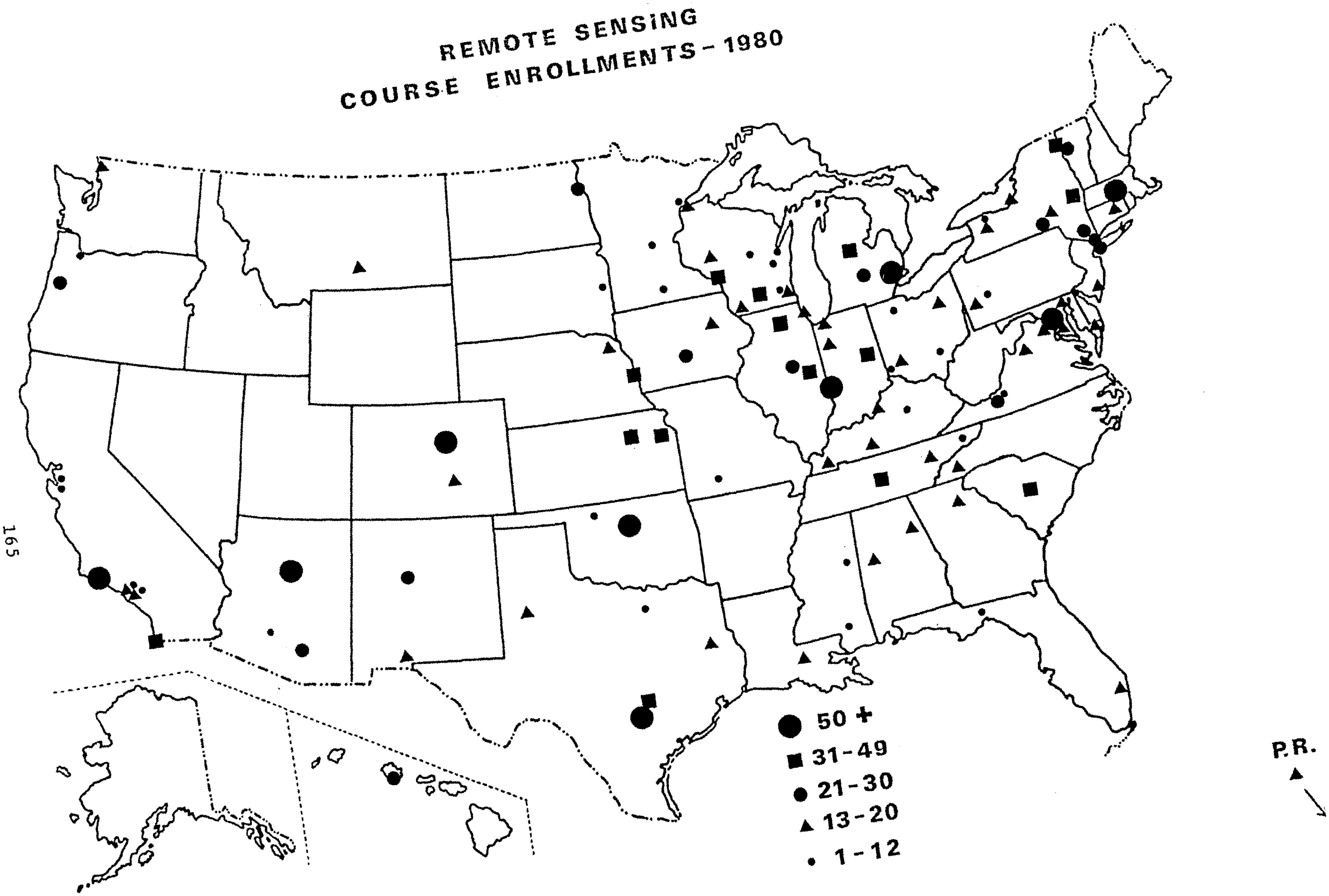
2. Guide to Graduate Departments of Geography in the United States and Canada 1980-1981, Association of American Geographers, Washington, D.C. 1980.

3. Schwendeman's Directory of College Geography of the United States, Dale R. Monsebroten, ed., The Geographical Studies and Research Center at Eastern Kentucky University, Richmond, Kentucky, April, 1980. (Vol.XXXI, No.1)

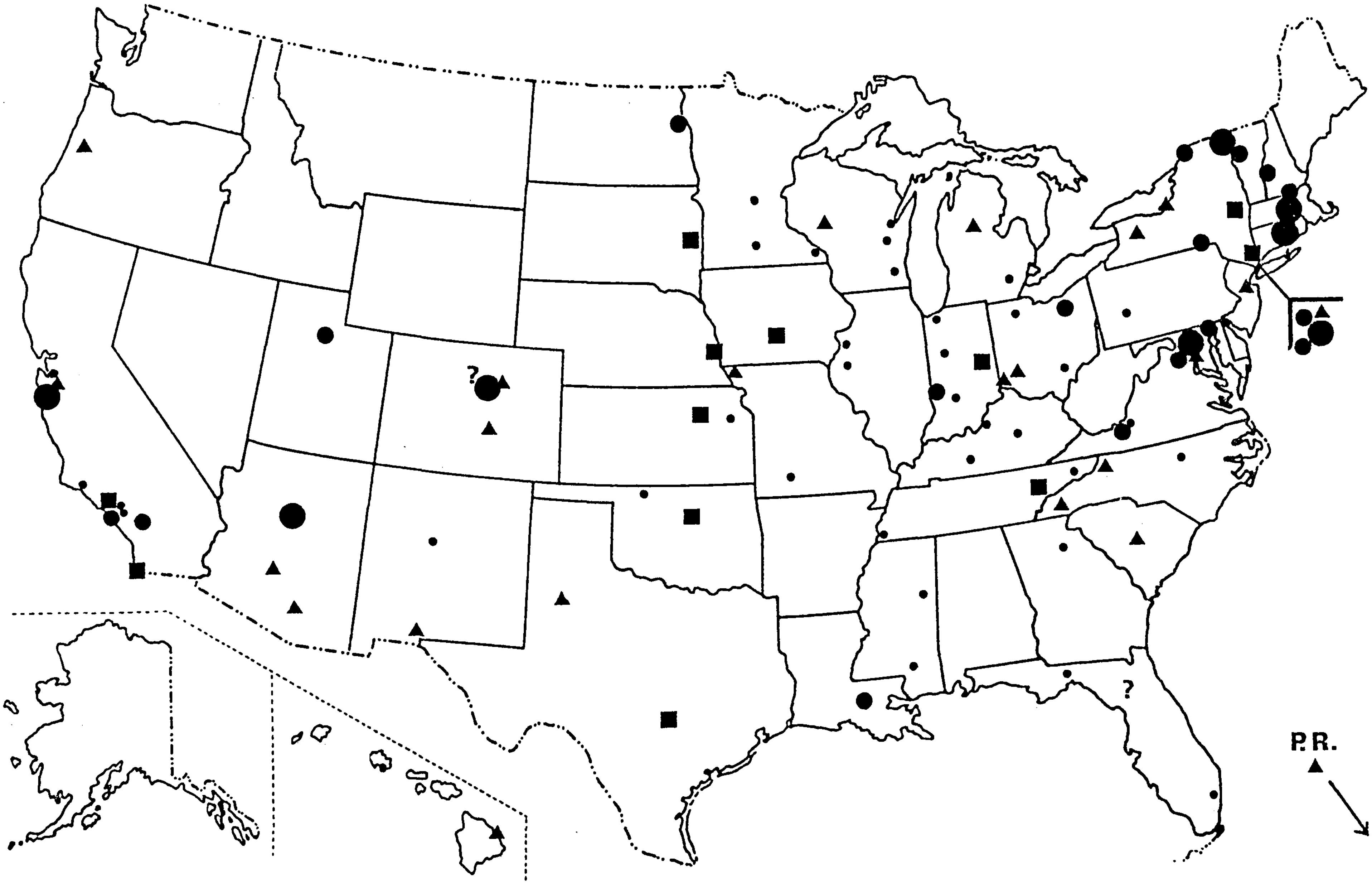
4. Schwendeman's Directory of College Geography of the United States, Dale R. Monsebroten, ed., The Geographical Studies and Research Center at Eastern Kentucky University, Richmond, Kentucky, April, 1981. (Vol.XXXII, No.1)

FULL-TIME FACULTY MEMBERS[a]
GRADUATE DEPARTMENTS OF GEOGRAPHY
1980-81




REMOTE SENSING
COURSE ENROLLMENTS - 1980
50 +
31-49
21-30
13-20
1-12
P.R.

REMOTE SENSING COURSE ENROLLMENTS - 1979



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CORSE-81

The 1981 Conference On Remote Sensing Education
May 18-22, 1981 Session No. 4c

PACKAGING FIELD, AERIAL AND LANDSAT SURVEYS FOR UNDERSTANDING MULTISPECTRAL ANALYSES

by

Noel Ring

University of Lowell

Concurrent instructor/student groundtruth and low-altitude aerial surveys during Landsat overflights allow immediate involvement in multispectral analyses of environmental conditions. Multipurpose aerial missions remain modest in cost and provide demonstrably useful multispectral slide data for student projects in mapping, monitoring and management evaluation. In Vermont, low-altitude 35 mm obliques of a recent forest pest control project actually "saved the day" when Landsat failed to provide adequate definition of defoliated areas. Correlations of field, aerial and satellite data thus also offers valuable lessons in resolution needs assessment.

Discussions during sessions of the ERRSAC and NOAA/NESS conferences at Danvers, Massachusetts in March, 1981 revealed great concern for the character and validity of groundtruth verification conducted in many applications research projects. Much concern is also voiced by environmental agencies, firms and organizations as to current college graduates being inadequately trained in field surveying and reporting techniques. Such "rumblings" should promptly renewed instructional emphasis in such areas at all levels.

Low-altitude aerial surveys are fraught with many hazards, least of which is actual danger to life and limb. Students are safer in a Cessna in the sky than almost anywhere on land! Nevertheless, fearsome perceptions persist and most institutions issue some form of liability release document to students about to embark upon a field trip. Legally, the main concern is negligence. Thus, advisably hire planes and pilots from licensed charter companies or regular commercial airlines.

Cost is the second most critical factor and can be ameliorated by arranging lab fee status for your remote sensing course. At $20.00 a head, funds accumulate readily for many hours of flight time, now ranging about $15-20.00 per student per hour. A four-seater Cessna currently rents for $35-40.00 per hour. Large course enrollments suggest use of a six-seven seat Cessna or an 18-20 passenger Dehavilland Twin-Otter, available from commuter airlines.

Mission planning for student research project remains an important and very time-consuming aspect of aerial surveys. Preparations involve mapping flight lines and targets, conveniently marked on clear plastic sleeves encasing standard air photo prints or high altitude aerial film positives. Camera provisions include proper films and filters as well as a Kodak grey card useful for calibrating light meter readings at ground level prior to flight. Incidentals range from dark clothing and eye-glass straps to plane window cleaners and motion-sickness preventatives, the best being to fly on calm days.

Standard 35 mm SLR cameras with 50 mm lenses are the most readily available tools for student aerial surveys. In New England, on a calm, sunny to mixed sun/clouds day, 64 ASA Ektachrome can be used at a .125 second speed with f8-11 aperture. This matched in another camera by Ektachrome infrared with a Wratten 12 or 15 filter will provide very enlightening multispectral data. Ektachrome IR film is just as sturdy and easily handled as its natural color counterpart, though has a shorter life span. Its use is a great aid to student understanding of IR rendition.

Kodak's black-and-white infrared film, while informative, is very hard to handle as highly light sensitive. In addition, the nearly opaque 89B filter required means that the photographer sees virtually nothing through an SLR viewer, prompting the need for a range or view-finder type camera. In sum, one roll, handled in a pre- and postflight darkroom, might be included in a spare camera for special targets.

Aside from coursework, students may well become involved in small scale contractual aerial survey work. In Vermont, weekly monitoring of forest pest control project test sites with color and CIR Film provided slides for simple backscreen mapping of damage in sprayed and control areas. The discovery that Landsat could not reliably distinguish areas of trees partially defoliated by forest tent caterpillars or maple leaf cutters, as compared to good renditions of areas decimated by gypsy moths, enhanced the importance of the low-altitude survey data.

High resolution and multispectral view needs for instruction and research are likely to increase the utility of 35 mm aerial surveys in the future. Both vertical and oblique photography are useful, the former being advisable when possible. Application of densitometry techniques to the film gives additional scientific measurability in data analysis. Although aerial surveys represent a significant effort in organization, effective planning can yield highly useful instructional materials at a fairly reasonable cost. When correlated with Landsat overflights, student field and aerial surveys provide the ultimate in "hands-on" experience in remote sensing from platform to product interpretation.

NASA

CORSE-81

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Applications of Densitometry in Remote Sensing Learning Experiences

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Introduction

An exciting and meaningful dimension to remote sensing learning experiences can be provided through the application of densitometry to a variety of concerns relating to both theory and applications. The use of a densitometer provides the student with a type of "hands on" experience in which direct manipulation of image products is involved, and the procedures are easily and quickly learned facilitating the collection and analysis of quantitative data on the radiometric properties of aerial photographs and satellite images. These data can then be used for examining relationships between image tones or colors and ground conditions.

Densitometry as an approach in the study and analysis of aerial and space imagery is not covered in many of the remote sensing texts. It is particularly refreshing to note the clear and concise treatment in the relatively recent text of Lillesand and Kiefer (1979) where the larger part of a chapter is devoted to this.

The major concern of this paper is to provide information on the use of densitometry in remote sensing courses at the University of Vermont, Department of Geography, and to point out that it is adaptable to most remote sensing instruction situations where cost of equipment and time are limiting factors.

Once the densitometric equipment is obtained and the basic concepts are understood, the door is opened to almost limitless explorations by both instructor and student. The use of densitometry can be brought into curricula at introductory and advanced levels, and this serves to stimulate additional interest for undergraduate term paper projects, as well as for graduate student projects and thesis research.

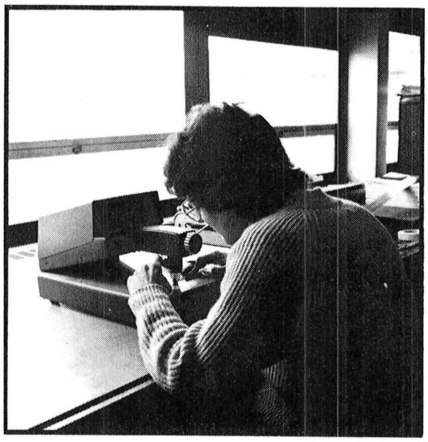
Equipment and Image Considerations

A basic consideration in obtaining equipment for instruction in any program is cost and equipment characteristics. The equipment currently in use in the Department Remote Sensing Laboratory is a Macbeth Model TD504 transmission densitometer (Fig. 1) which may be used with transparency films either in black and white or color (normal or color infrared) presentations. While this particular densitometer is of the more expensive variety, it offers considerable versatility, and can be coupled to auxiliary print out equipment if available. One can expect the cost of densitometers of the type shown in Fig. 1 to range between 2 and 3 K dollars and as the price of remote sensing equipment goes, this is not particularly expensive, and thus it may be an affordable item of many.

The basic components comprising the densitometer can be readily seen from a schematic as shown in Fig. 2 (from Lillesand and Kiefer, 1979). It should be noted that the filter assembly shown in Fig. 2 is a vital element in the system if it is to be used for color determinations using normal color or color infrared transparencies. The characteristics of the filters within the filter wheel are described by transmission curves shown in Fig. 3. Blue, green, red and visual filters are employed. These filters are used for density measurements for the respective dye layers found in color transparencies, while the visual filter covers the full range from and including blue through red. When working with black and white transparencies, the visual filter is employed.

Imagery in transparency form is no longer difficult to obtain. The EROS Data Center Sioux Falls, S. D., has large volumes of all types of transparencies ranging from multiband panchromatic to normal color and color infrared. The use of LANDSAT transparencies is also possible and the densitometer provides a means for obtaining quantitative data of a relative type where digital processing equipment is not available.

An additional transparency product is particularly useful, if not essential in some cases, and that is the standard 21 step gray scale that is usually found on the leader of the film roll. This should be requested along with the imagery and photographically processed along with the duplicate imagery to be ordered.



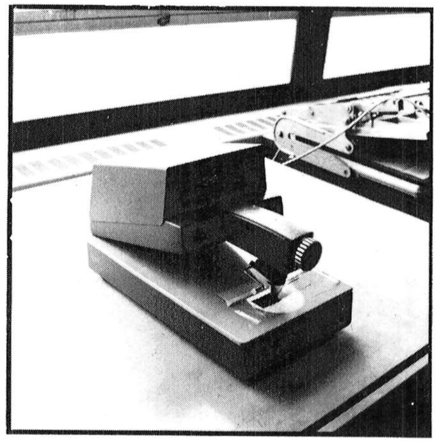


Fig. 1. The Macbeth TD504 densitometer in use by a student. This equipment is compact, easily transported and can be operated by students with just a few minutes of orientation.

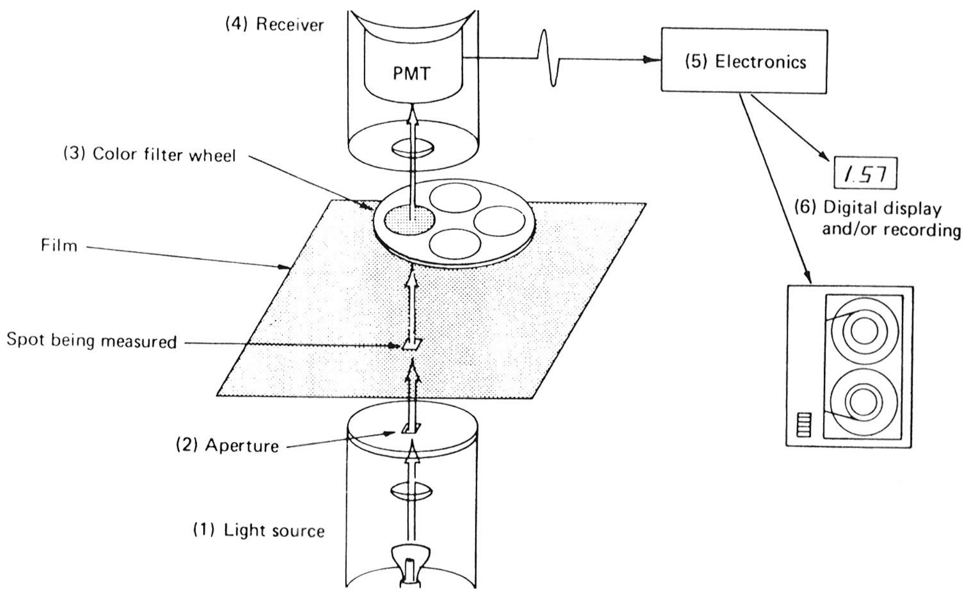
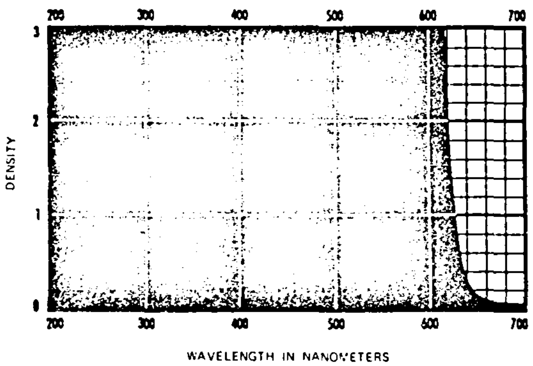
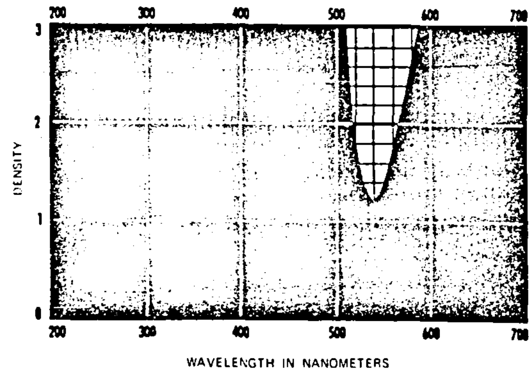


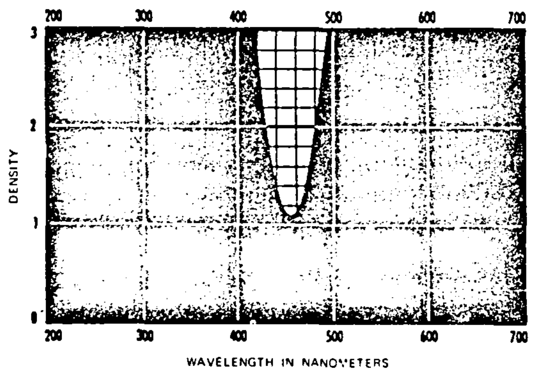
Fig. 2. A typical schematic of the transmission densitometer (from Lillesand and Kiefer, 1979). As may be seen, the transmission densitometer provides a measurement of the film opacity/transmission at "spot," (Density = $\log_{10}$ (Op) = $\log_{10}$ $(\frac{1}{Tp})$.



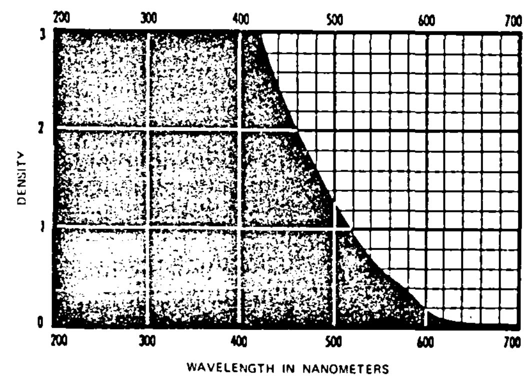
92 – Red – (TD-504)



93 – Green – (TD-504)



94 – Blue – (TD-504)



106 – Visual – (TD-504/A/M)

Fig. 3. Filter characteristics for the TD504 transmission densitometer.

Instructional Uses of Densitometry

It would not be possible to describe all of the potential applications of densitometry in remote sensing instruction within the space allotted so some examples are used here based on experiences drawn from the remote sensing courses taught at the University of Vermont. These are described in terms of activities, all of which form the basis of exercises.

Activity #1 Description of a characteristic curve

This activity focuses on assessing the basic properties of a film by relating image densities to the exposure levels that produced them. The students are given the film leader containing the 21-step gray scale and proceed to record densities for each step. These are then plotted onto a graph paper in the standard format for characteristic curves where relative log exposure is on the X axis and density is on the Y axis. The curve generated from this activity is then analyzed in class to clarify the significance of the curve. The student identifies the toe, shoulder, and straight line segments and proceeds to calculate the gamma (4) or slope. An extension of this activity would then be to compare different types of film to investigate how film "speed" may bring about changes in the overall curve. Other concepts that can be examined include radiometric resolution, contrast and exposure latitude.

Activity 2 Color assessment

Normal color and color infrared transparencies are used in this experiment, and the object here is to develop some familiarity with color measurement and nomenclature. The concepts of hue, saturation, and intensity are explored since the student is given several areas on color imagery examples. The Munsell System is introduced through the use of this data. The procedure used in this activity is based on that described in the Manual of Color Aerial Photography (ASP, 1968).

Activity 3 Investigating crop cover types on multiband photography

American Society of Photogrammetry test photography (1:60,000) is used for this activity centered on cropland use in Phenix, Arizona, area. In this case, gray scales were photographed so it is possible to assess the effects of atmospheric attenuation in the imagery sets used. (Panchromatic 47B filter-blue, 58 filter-green, 25A filter-red and Pan. Infrared film 89B filter) Various crop cover types are examined in a test area where ground truth information is also available. Density measurements are made to produce mean densities for various crop cover conditions. A classification based on the compound means is then devised and these results are then extended to classify other area in the scene.

Other Activities

The densitometric approach has been used by students for classifying wetlands, water bodies and terrain conditions. The opportunities seem endless, and more importantly the students find the experience enjoyable and rewarding.

References

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Lillesand, T. M. and R. W. Kiefer (1979) Remote Sensing and Image Interpretation, John Wiley, New York.

Acknowledgments: Macbeth Color and Photometry Division of Kollmorgon Corp. for Fig. 3.

Sam Jung and Patricia Poundstone - students at UVM for photography.

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DEVELOPING AN UNDERGRADUATE GEOGRAPHY COURSE ON DIGITAL IMAGE PROCESSING OF REMOTELY SENSED DATA

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In 1978 the Department of Geography at the State University of New York College at Oneonta was awarded a National Science Foundation Local Course Improvement Grant to develop an undergraduate course on digital image processing of remotely sensed data. This report examines some of the curricular problems encountered in developing and presenting this course and how these problems were handled.* Although each department and university is unique, the comments made here may be applicable to other instructional environments.

Background Conditions

In order to appreciate some of the difficulties experienced in creating this course, a brief description of certain background conditions is needed. The College at Oneonta is one of twelve four-year liberal arts colleges within the SUNY system. The college has approximately 5500 undergraduates and 600 graduate students. Historically, the college's major areas of concentration were teacher education and home economics. The liberal arts

* The course is team taught by the author and Dr. Thomas J. Gergel of the Department of Geography.

disciplines did not develop major programs until the early 1960s. Thus, the college does not have a strong background in the technology areas. No major programs exist in either computer science or statistics, two basic components used in the processing of digital images. Courses are offered by the Math Department in these two areas but emphasis is placed on the theoretical rather than the applied aspects of these fields resulting in a situation where students receive little "hands-on" experience. In fact, the Geography Department, although small - five faculty members and 65 majors - is the largest academic user of the college's computer facilities. The department offers a solid undergraduate major with a strong emphasis in the area of geographic techniques. The college's computer facilities have been far from ideal for either instructional or research purposes. The main frame has been Burroughs B4700, a decimal machine designed for business applications. Most work has been done in the batch mode because of the main frame's limited interactive capabilities. Within the last month the college has installed a Burroughs B6810 which will overcome some of the problems. Thus, to offer a highly technical course within this environment many curricular problems had to be overcome but only the major ones will be addressed in this report.

Computer Resources

The first major problem encountered in developing the course was to obtain the necessary computer facilities to analyze images digitally. The Geography Department was strongly committed to presenting this course in a "hands-on" environment rather than on a strictly lecture approach. In order for students to understand and appreciate the interrelating and complex techniques involved in analyzing remotely sensed data using digital image processing, they needed first hand experience. To take this pedagogical stand was one thing; to implement it was quite another thing. The major hurdle was acquiring the required computer resources. Like many colleges and universities funds for new equipment are extremely limited at Oneonta. It was not possible to obtain an $80,000 minisystem, a $40,000 image processor, or even a $20,000 microsystem. Of course, funds for hardware can be obtained from outside grant sources but such sources rarely provide for on-going maintenance costs. In addition to the funding problems for hardware, the college does not have the expertise either to set up such equipment or to integrate it into existing facilities. The Computer Center provides one staff member for academic work, and this person is a programmer, not a systems analyst. The computer science courses are offered by mathematicians who possess little interest in computer hardware. Thus, it was apparent that to establish the computer facilities needed for this course existing hardware had to be used.

In addition to hardware, software was required. A number of software packages for digital image processing are available at reasonable prices. However, many of these packages have special routines which make them machine dependent and/or have software which allows them to use special graphic input-output devices. No available packages existed for a Burroughs B4700. Also, packages are frequently difficult to modify in order to accommodate new techniques which a user may wish to integrate into the system. Users are often locked into the existing capabilities of a purchased package because they do not know the numerous computer algorithms employed in developing the package. After reviewing several software packages, a system developed by NASA's Earth Resources Laboratory (ERL) was used to form the building block of a new system. This package was far from being ideal for the Oneonta environment but the author had received considerable experience in the use of ERL software and hardware. This knowledge plus his extensive programming experience allowed him to select those programs from the ERL package pertinent to the Oneonta environment and to modify them for the existing hardware and for the development of an in house software package called Landsat Analysis Package (LAP). The LAP system not only consists of the modified ERL software but also of new software developed by the author based on his experience in the fields of computerized cartography and geo-information systems and on techniques used in other digital image processing systems.

Obviously, most geography departments are not going to have an experienced programmer on their staff to build such a system. At the same time many colleges and universities have considerably better computer resources and support than Oneonta. To purchase a system may appear to be the easiest and best solution to the problem but commercially developed systems contain many unknown pitfalls for the unsuspecting novice. If a geography department wants a computer system to teach digital image processing, such a system frequently can be developed by using existing resources. The real task is identifying the available resources and molding them towards a particular goal.

Course Prerequisites

The second major problem was establishing the necessary prerequisites for the course. A list of desired courses was made based on the following topics: electromagnetic radiation, multivariate statistics, digital processing, aerial photo interpretation, and ground truthing. Courses dealing with each of these topics are available on campus but like many undergraduate geography programs the Oneonta program must face the reality that few freshmen upon entering college declare themselves as geography majors. In fact, some students do not discover geography until their junior year, and then they must try to complete the major within their senior year. Such a condition makes it almost impossible to develop a prescribed schedule for students, and thereby, form the building block courses for advanced courses. If courses for all the aforementioned topics were made prerequisites for the remote sensing course, very few students would be able to take the course. Courses with small enrollments come under close scrutiny by today's economy minded college administrators. Because of the available computer resources the course already had been limited to fifteen students. Since the course was being team taught by two professors, one professor had to teach it as an overload because of the limited enrollment. Thus, within this type of environment it was deemed impractical and unwise to place any prerequisites on the course. However, the basic problem still existed: "How to handle student deficiencies without spending valuable time covering essential background material?" This problem was further complicated by the decision to dedicate a large segment of class time to "hands-on" experience.

To overcome the prerequisites problem, students were placed into three-member teams. These teams worked together throughout the course on assignments. Members of a team were selected based on their background and areas of interest. Each team had at least one member with some course work in statistics, computer science, and aerial photo interpretation. The team members not only complemented each other they also helped each other to overcome their deficiencies. The team approach also reduced the demand on the computer resources making it possible to increase the class size. With the new computer, adequate resources are available to permit each individual student the opportunity to work alone but based on the success of the team approach, it will be continued. Although individual deficiencies continued to exist at the end of the course, it was possible to present the course without having to cover a large amount of basic material.

Size of Study Areas

The next problem encountered related to study areas. Should there be many small study areas each dealing with a particular topic or problem or should there be large study areas with one area being assigned to each team? With the small study areas each team would work with each area throughout the semester, and thereby, gain experience with a variety of problems. The small study areas would be approximately 50 elements by 50 scan lines in size and each area would deal with either a different type of land cover such as forest region versus an urban area or a different surface condition such as snow cover, shadows, or clouds. The small area would require less computer time to analyze and less disk space to store. The large study areas would be about 300 elements by 300 scan lines in size. Each team would work exclusively with one area throughout the semester. Each study area would relate to one major type of land cover but due to the size of the areas, they would provide a variety of surface conditions. For example, a small study area concentrating on urban land cover may show only the old central city; whereas, a large area could provide not only adequate coverage for the central city but also the suburbs, the urban fringe, and surrounding rural lands.

After examining the pros and cons of both approaches a decision was made to use the large areas. In any course, time is an important factor in deciding what instructional approach to employ. It was felt that students would not have adequate time to work with a reasonable number of small areas within a semester. Also, it was considered important that students experience the total range of decisions encountered in analyzing an image starting from defining a problem to producing a final product. Students appeared to enjoy working with one large area. They liked the opportunity to become familiar with an area in detail and to produce a meaningful product. The final product gave them a sense of accomplishment. It was the culmination of their struggle to learn about image processing. It was their merit badge which they proudly displayed and which, by the way, became an excellent device for promoting the course. Also, in working with one large area with a particular goal in mind the team members developed strong ties making for good, working teams. Students, likewise, learned a lot about analyzing other land cover surfaces because teams were constantly discussing and comparing their respective areas. Overall, the single, large study area approach has produced very rewarding results.

Summary

In summary, three problems relating to the development of a digital image processing course in an undergraduate geography environment have been discussed in this report. Several other major problems existed and many small problems occurred in the building of this course but time and space do not provide the opportunity to describe all these problems within this written report. Personally, when first starting to create this course, it seemed an impossible task, especially at the undergraduate level, but through persistence the course materialized. Although the instructors of this course teach other courses, they have found this course a very rewarding one. Due to the nature of the subject and the way the course has been presented, one could see undergraduate students suddenly discovering the excitement and joys of conducting research and realizing the significance and the interrelationship of what appeared previously to them as many disjointed pieces of knowledge that they had been exposed to in numerous other courses. For both the instructors and the students it has been a very rewarding experience.

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THE FIRST YEAR: DEVELOPMENT OF A LANDSAT CAPABILITY AT SAM HOUSTON STATE UNIVERSITY

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In 1979 Sam Houston State University was a hundred years old as an organized school. Geography has been taught at the school since its earliest years with the first teacher being a member of the Natural Science Department. In 1968 after a few years of preparation a course in map reading and air photo interpretation was begun with very basic equipment. Since 1968 air photo interpretation has been a requirement for all majors. In 1980 one faculty member in the Department was able to attend a National Science Foundation Grant in Remote Sensing at the University of California-Santa Barbara. The faculty member who designed the course in air photo interpretation was experienced as an Army Air Corps photo interpreter in England during World War II. The faculty member who ended up teaching this course was experienced in geographic lab and field work and had additional experience in the U.S. Army Anti-aircraft Artillery, as a radar and computer repairman, and in some intelligence work during the Korean War.

Sam Houston State University is a State institution in Texas with an enrollment near 10,000 students. The school could be described as a regional university which is assigned to service a particular group of counties in Southeast Texas. In former years the school was called a Normal School and a Teacher's College. Several colleges are present within the University and much of the growth of the school dates from about 1960. At present growth is on a plateau but several departments and colleges are experiencing continued or new growth. Geography is among those departments which are at a plateau level. In research, Sam Houston State University ranks ninth in the State of Texas on the basis of money received through grants from various sources.

The Geography Department of Sam Houston State University has a long tradition dating back to the beginning of the school. Its major growth has been since 1960 and today it has five faculty members, two with Ph.D's from Oklahoma, one with a Georgia Ph.D. and another with a Tennessee Ph.D. The final member has a Master's degree from Oklahoma and a.g.w. from Texas A & M University. At present cartography, map and air photo interpretation, and field geography are taught by the faculty member from Tennessee. This same faculty member had the NSF grant in remote sensing. So, one faculty member in the department has had responsibility for what remote sensing teaching has occurred since 1968.

The geography lab for cartography, also serves for map reading, air photo interpretation, and field geography. No other classes are allowed to use this specialized room because of the delicate nature of the tables and equipment. The equipment in this lab is rudimentary rather than sophisticated and includes a Nikon mirror stereoscope with stereometer, pocket stereoscopes, a good teaching library of maps and photographs and sufficient drafting equipment to produce maps in India ink and rub on letters and patterns. The production of a finished land use map which involves map reading, air photo interpretation, cartography, and field geography is a standard requirement of this course. It is expected that this same room will widen its activities into remote sensing of Landsat data.

The only questionable situation which seems to inhibit the continued development of the geography program is the retrenchment program which the University has been ordered to pursue. For geography this means a reorganization into a combined department which features biology, geology, environmental science, and geography. The Fall semester of 1981 will be the first semester under the new program. Since remote sensing is very likely to enhance all these fields of endeavor it will probably broaden its activities because of the merger of departments.

In order to institute Landsat data processing a careful analysis of the present school computer is needed. At our school a new computer has been in use about a year. It is a DEC 2050 with a capacity of about 384K words. The Computer Science Department and Computer Center staff use this computer to teach classes in computer science with languages such as: Fortran, Cobol, Basic, and Pascal, etc. The computer also handles student records, registration, classroom records, and performs some research function. A small home computer is also present in the Physics Department. Both computers have the ability to handle Landsat data analysis with the proper synchronization and additional hardware and software.

The initial program we decided to look at was "IMAGES" by Prof. John Jensen, Department of Geography, University of Georgia which is an improvement of the "DOGMA" program as used at the University of California-Santa Barbara. Both programs are similar and use the BASIC language. The IMAGES program was designed for teaching purposes but will do research problems, too. So far our school computer has been able to sync quite nicely with the IMAGES program but the lack of documentation has caused some difficulty with the computer staff. Each computer uses slight differences in the way Basic is fed through the system so the computer staff will have to adjust for the version of Basic which it uses.

The computer science rooms have standard video terminals and a few printers for student use which can handle 1,200 lines per minute. One of the positive features of this computer set up is that the school offers free time and the free use of tapes, disks, and other software items. The Computer Center staff will, also, provide assistance of whatever nature is needed. The negative aspect of the Computer Center is that no color display, color enhancement or plotters are available. One problem which we had in the very beginning was that our computer only reads 1600 BPI and our first Landsat tape was 6250 BPI. It will be necessary to have all our Landsat library items in 1600 BPI. At present the Computer Center will only allow slow moving programs to operate in daylight hours but batch method programs are allowed at night.

Our first permission to form and operate a Remote Sensing Committee was given by a Dean in August, 1980. Within a few months the Committee was formed from volunteers and includes: four mathematicians, two biologists, two in geology, two in agriculture, two in industrial arts (drafting), one each in science education, fine arts, philosophy, library, English, and geography. Two faculty are in the Computer Center or computer science. We felt that this was a good showing for a faculty of 350 or more.

The Committee appears very strong in its formative years but most know little or nothing about Landsat. To alleviate this problem I started a faculty newsletter to teach the fundamentals of Landsat before initial contact with the computer was begun. It was suggested that those with no computer experience take a beginning course or read up on the topic from the large supply of literature in my office. The NASA facility at Bay St. Louis, Mississippi has suggested we come over for a week of schooling but this has proven to be impossible with the complicated schedules and yearly activities of our Committee members. We may have to learn on the job.

Texas A & M University and its Remote Sensing Department is only 54 miles down the road from our school and has a very advanced program in remote sensing almost totally invested in research and production. They have suggested, most correctly, that they might very well be the best help which we can get because of our close proximity and the fact that Texas State colleges and universities are hooked up to a common long distance telephone network.

It is our hope to build a small remote sensing facility with a special emphasis on knowledge transfer to the public schools and with some research so that we can be aware of all aspects of Landsat analysis. One innovation which we will try is the use of fine arts techniques in the final presentation of a Landsat image.

The administration of our university looks upon new program ideas in a favorable light. The overall limiting factors are quick financing because of budgets being made out on a biennial basis in harmony with the State Legislature meetings, student interest and enrollment, faculty interest for teaching and research, equipment availability and classroom space, etc. Another reason for a positive approach toward this field is that it is new. It also affects enough departments in the school so that we can expect their cooperation in applying for an NSF equipment grant on a matching basis.

The goals of our first year include: getting on the air with our IMAGES program and one Landsat tape, to acquire more library materials and educational teaching aids, to train our Committee members, to open lines of communication with various government and private organizations in remote sensing, and to remove all obstacles which impede the development of this program. For the second year, we look forward to goals, such as: an NSF equipment Grant, further training of our Committee members, a trial run on a remote sensing class using Landsat analysis, a beginning on our main goals of a research project and information transfer to the public schools.

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REMOTE SENSING RESEARCH IN GEOGRAPHIC EDUCATION: AN ALTERNATIVE VIEW

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THE PROBLEM

Geography currently plays a major role in remote sensing education in this country (Estes, et al., 1977), with the emphasis today on training students in the application of remotely sensed observations to geographic problems. This emphasis reflects a prevailing view of remotely sensed data interpretation as a well-established body of techniques to be applied in solving a broad spectrum of geographic problems. This view is also apparent in what we see as the current emphasis in geographic remote sensing research on applications studies. The underlying assumption of this applications orientation is that the information content of remotely sensed data is known and coincides with the types of information required for particular purposes.

There is some question as to the degree to which analysis of contemporary remotely sensed data for applications purposes is satisfactory. The categories of information typically of interest in applications work (e.g., Anderson, et al., 1976) have not proved to be interpretable from current remotely sensed data with consistency and confidence. This situation raises doubts as to the degree to which the information contained in the current generation of sensor observations of the earth's surface is understood.

SOURCE OF THE PROBLEM

Modern remote sensing systems have been criticized by some investigators as not being effective in providing the types of information for which the use of traditional observation systems (e.g., aerial photography) has been proven successful. While this criticism may be viewed as merely a conservative reaction to the appearance of new technology, it is a valid criticism. The advent of remote sensing from space occurred during a period in which American geographical photointerpretation work emphasized applications (Stone, 1974). Investigators appear to have turned to the new data as another means of solving the same types of geographical problems to which they had been applying aerial photography. There was no phase of theoretical investigation of these new data comparable to that which had preceded the applications phase in aerial photographic interpretation.

Not surprisingly, investigators have encountered difficulties in addressing a set of problems that have remained the same with data that have changed markedly. The spatial, temporal, and spectral/radiometric parameters of new observation systems are significantly different from those of what may now be regarded as "traditional" systems. The major innovations associated with remote sensing from space are as follows:

1) spatial: uniform observations are acquired on a global scale, and are more generalized;
2) temporal: coverage is of significantly higher frequency;
3) spectral/radiometric: observations are numerical measurements, in many wavelength bands.

These features have a number of implications for the extraction of geographic information from these new data. For example, the spatial resolutions typically encountered in these new data are coarser than those characteristic of most aerial photography. The relationship between images in photography and features on the ground is fairly well understood as a result of accumulated experience in extending visual perception of the surface to aerial perspectives. However, there is no reason to assume that the associations which can be made at one scale are valid at another. Furthermore, sensor systems do not necessarily generalize landscapes in ways consistent with our conceptual or cartographic generalizations. Similarly, the increased temporal resolution possible with satellite observing systems is quite different from that of "traditional" systems. Aerial photographic missions are usually planned for a time of year considered to be optimal for a particular application (e.g., tree identification), and repeat coverage is rarely obtained more than once every five years. As a result, the selection of an appropriate observation date from among the many available for a given geographic location becomes problematical with these new data.

Analysis of remotely sensed data in numerical format has been put forward as a possible solution to some of the difficulties presented by the characteristics of these new observations. In particular, analysis of the numerical data at the resolution limit of the sensor and utilization of all wavelength bands simultaneously has been expected to provide information about the surface in greater detail than that which human beings are able to extract from visual assessment of imagery. Automated interpretation has also been seen as a means of efficiently utilizing a data base that has been accumulating with unprecedented rapidity.

The spectral signature paradigm, widely employed in computer-based interpretation of the multivariate, numerical data, has not met with resounding success. For example, a survey (Jayroe, 1978) of investigations using digital Landsat data to classify land cover indicates that classification accuracy figures are on the average significantly lower than the minimum criterion of 85 percent often used for visual image interpretation (Anderson, et al., 1976). Furthermore, spectral signature methods give acceptable results only over very limited areas and only at certain times. In addition, these methods nearly always require significant amounts of ancillary ground information. As a result, automated interpretation has yet to be proven as a means of exploiting the global and temporal coverage afforded by satellite data. Apparently, the numerical analysis techniques in wide use are unable to address effectively the problems raised by the features of contemporary remotely sensed earth observations.

We believe that others, like ourselves, have found that the results of analysis of these new data have not conformed to initial expectations. However, we do not believe that these new observation systems should be rejected. We suggest that the problem lies in our limited understanding of the nature of the data now being acquired. A comprehensive understanding of the spectral, spatial, or temporal properties of landscapes, as observed with contemporary earth observation systems, has not yet been developed.

WHAT NEEDS TO BE DONE?

We see a need for basic research to determine the inherent information content of the data. An approach that we propose is to consider remotely sensed data as a measure of one or more unknown or poorly-understood landscape attributes. The hypotheses for this research should originate in examination of the remotely sensed data rather than from external objectives. The goal of this research is to establish models of landscapes that may be used to explain the information content of remotely sensed data.

One hypothesis that should be investigated is whether remotely sensed observations provide measures of continuously distributed landscape physical attributes -- for example, moisture content, thermal inertia, and chlorophyll content -- rather than simply indicating the presence and extent of discrete categories or objects. To test this hypothesis requires a thorough knowledge of the interactions between electromagnetic energy and landscapes, as expressed in the spectral/radiometric component of remotely sensed data. Study of these interactions is prevalent in remote sensing research conducted in the non-photographic regions of the electromagnetic spectrum. For example, microwave remote sensing research is concerned with the influence of moisture on observations; thermal properties are considered to be key landscape attributes in explaining thermal infrared observations. This approach is not often taken in the peak energy range of the solar spectrum (visible and near-infrared), because data such as those acquired by the Landsat system tend to be viewed as merely an extension of what is already known from experience with photographic observations. However, we believe that this presumption is not correct. New remotely sensed data cannot be viewed simply as a direct extension of our visual capabilities.

Additional study is needed to investigate the relationships between the radiometric measurement of landscape attributes and spatial and temporal factors. For example, one hypothesis might be that the ability to measure a particular landscape attribute is invariant as a function of the spatial resolution of the observing system. Although one might expect different attributes to be measurable at different scales of observation, relatively little is known about the ways in which sensors generalize the surface as a function of observation cell size. If the ability to measure a particular attribute is found to vary with scale, then a new focus for investigation becomes the determination of the scale range over which the attribute is measurable.

With respect to temporal factors, an initial hypothesis that should be examined is that a given landscape attribute is measurable at all times. The consistency and precision of that measure may in fact vary with time -- for example, because of variations in factors external to the landscape, such as seasonal differences in intensity of solar radiation.

WHO SHOULD DO THIS RESEARCH?

Specialists in many disciplines have contributed to advances in remote sensing of the earth's surface, including engineers, mathematicians, physicists, agronomists, geologists, and others. However, investigators in each of these disciplines understand and are concerned with only a part of the observed landscape and/or of the data. The data, in contrast, are holistic, in that they represent integrated observations of landscapes. Geography is the discipline that claims an integrated approach to landscapes (Fenneman, 1919). Therefore, geographers bear a major responsibility for basic research on the remotely sensed observation of landscapes.

While our contention about the unique approach of geographers would meet with little disagreement, the conclusion we draw with respect to the role geographers should be taking in basic remote sensing research is perhaps less widely accepted. Geography as a discipline appears to view itself largely as a passive user of remotely sensed data, principally interested in using the data as an adjunct to current research objectives. The development of analysis techniques, theories, and specifications for future system designs is left to other disciplines. Many geographers view basic remote sensing research as "non-geographic," since it is seen as being concerned with "technique" rather than with what is regarded as substantive geographic inquiry.

This attitude has hindered geographers in making remote sensing research contributions commensurate with the breadth of geographers' perspectives on landscapes. We cannot depend on others to develop theories and paradigms for us. The concerns of the systematic disciplines are not necessarily coincident with our own. Geography is the only discipline which takes an integrated approach to the explanation of areal differentiation on the earth's surface. We routinely apply this approach in attempting to explain field observations and ground measurements. Remote sensing systems provide new observations and measurements of areal differentiation. We must assume our responsibility to seek new theories to explain the data and to provide others with the benefits of our insights.

SIGNIFICANCE OF THIS APPROACH

Remotely sensed observations of the earth's surface raise questions that are particularly geographic in their form and scope. Geographers have contributed significantly to development of aerial photointerpretation techniques by detailed examination of the information contained in the photographs. The new generation of remotely sensed observations has yet to be examined with such rigor. This failure to conduct the needed basic research has constrained our ability to extract and apply the geographic information contained in these new data. We contend that the research approach we are proposing will not only improve applications of these new observations to geographic problems of current interest but will also provide new ways of examining landscapes that may directly contribute to advancement of geographic methodology and theory.

The demonstration that remotely sensed observations of the earth's surface consistently measure selected attributes of landscapes should enable the construction of models that describe the relationships between landscape factors (e.g., spatial arrangement, vertical extent of landscape elements within the observation cell) and the attributes as measured in the data. These models should then serve to enhance the utility of remotely sensed observations for collecting information about the surface. For example, this approach should lead to an improvement in our ability to use the data to identify and map nominal classes by providing a physical basis for explaining and predicting the degree to which any ground category is distinguishable from others present in the landscape. This knowledge should also serve as a guide in the selection of remotely sensed data appropriate to a particular problem. In addition, if the data provide consistent measurements of landscape attributes, nomothetic solutions to the interpretation of the data should be possible which will allow analysis of the data from any geographic location, with a minimum of ancillary information.

The potential of remote sensing as a new source of geographic knowledge about the environment has not been fully exploited (Bowden, 1977). We expect that the attributes measurable with remotely sensed data will serve as new indicators of landscape conditions. For example, if these observations provide a measure of the degree to which a landscape is photosynthetically active, we have a new means to study the biophysical functioning of landscapes in relation to natural and cultural factors. This integrated expression of landscape dynamics should be highly amenable to modeling, and model refinement should be facilitated by the availability of a large data base against which to test model predictions. The results of this research could lead to significant new geographic concepts that would assist in environmental analysis and resources assessment as well as contribute to advanced understanding of landscapes on a global basis.

IMPLICATIONS FOR REMOTE SENSING EDUCATION

Within many geography departments remote sensing is viewed as a mere "technique" a student should learn in order to carry out "true" geographic research. This view inhibits both students and faculty from investigation of remotely sensed data as a new source of geographic knowledge that may alter our understanding of the earth. The tendency has been for geographers to accept these new data and analysis techniques from engineers and mathematicians without questioning the accompanying premises. This "black-box" approach has hindered geographic applications of the new remotely sensed data and has limited the geographer's contribution to further development of remote sensing observation systems.

We suggest that geographers accept their inherent responsibility to contribute to the development of remote sensing through pursuit of basic research along the lines we have proposed. This research can be encouraged, particularly among students, by demonstrating the links between geographic theory and remotely sensed observations, encouraging a healthy skepticism concerning our current understanding of these data, and suggesting possible avenues of research which may improve our understanding. The incorporation of the framework of inquiry proposed here into current geographic remote sensing research and education presents a challenge. Rising to this challenge will, by bringing the full weight of the geographic perspective to bear on these new observations, contribute to the realization of the inherent value of contemporary and future remote sensing systems. At the same time, pursuit of answers to questions such as those we have posed should enhance our understanding of landscapes.

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Additional comment related to A. Hawley's presentation:

Comparison of Dahlberg's report (Session 1) and Schwendeman's directory (see bibliography).

		Schwendeman	Dahlberg
Geography Depts. 1979 & 1980		266	249
Air Photo Courses	'80	242	229
	'79	234	
Remote Sensing Courses	'80	108	238
	'79	91	
Total (in either year)		132	

Courses in remote sensing should theoretically appear in geography graudate programs (if any remote sensing courses are offered at all).

NE US and CA have most full time faculty members (graduate departments of geography) in 1979 and 1980.

Remote Sensing courses offered by these departments of geography roughly correspond with the distribution of full time faculty members.

Some inconsistencies are apparent (e.g., some courses with more than 50 students enrolled in 1979 are not present in 1980)

Additional comment related to A. Lind's presentation:

Lillesand and Kiefer text is only text which adequately covers densitometry; "unfortunate - densitometry is a basic" remote sensing tool. The field is now overwhelmed with machine processing. Use spot densitometer (scanning densitometers are too expensive, and students will understand concepts of both).

IMAGE SCALE & DENSITOMETER
SPOT SIZE (APERTURE)

	(APERTURE)	
SCALE	0.7mm	1.0mm
1:5000	3.5m	5m
1:10,000	7.0m	10m
1:40,000	28.0m	40m
1:80,000	56.0m	80m
1:1,000,000	700.0m	1Km

Participants in Geography Discussion

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BEETS, John
BETANCOURT, Jose
BOUNDS, John
BROPHY, David M.
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CONANT, Francis
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LOUGEAY, Ray
LUDWIG, Gail S.
LUMAN, Don
MANO, John Margaret
MARTIN, Curtis
MCCOY, Roger M.
MCCORD, Tom
MONSEBROTEN, Dale
MORROW-JONES, Hazel
MYERS, Sister Marjorie
NICHOLS, Woodrow W. Jr.
RAWDEN, Fiske
RAY, John R.
RIECK, Richaad
RING, Noel
SCHWARZ, David
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WEBER, Veil V.
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Session 4-D

Geology

Highlights:

The geology session was chaired by Dr. Floyd Sabins, University of California at Los Angeles, and Dan Krizan of Purdue University was the reporter. Two papers were presented during the session, the first by R.W. Blair, Jr., Fort Lewis College, on "Using Landsat Imagery as a Basis for the Understanding of the Physiographic Regions of the United States" and the second by Kenneth Kolm, South Dakota School of Mines and Technology, on "Methods of Training the Graduate Level and Professional Geologist in Remote Sensing Technology." Summaries of both papers follow.

Dr. Sabins summarized the session for this report: There was a notable lack of complaints about present and future cuts in Remote Sensing research funds from government agencies. Instead there was a positive attitude toward determining how to succeed in the new environment. Alternate sources of funds must be developed; graduate students may need to provide more of their own support. Instructors will need to seek out and utilize resources on their own campuses.

The group felt that CORSE-81 was successful and that a future session would be beneficial, especially with higher participation of earth scientists. It would be beneficial to provide a geologically oriented field trip with a future CORSE meeting.

CORSE-81

The 1981 Conference On Remote Sensing Education
May 18-22, 1981 Session No. 4D

Using Landsat Imagery as a Basis for the Understanding of the Physiographic Regions of the United States

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Introduction

Fort Lewis College, Durango, Colorado, offers a sophomore level course entitled Physiographic Regions of the United States, which uses Landsat imagery as its prime "vehicle" to an understanding of the regional geology across the U.S. The problem with most regional geology courses is the difficulty of students to relate various geologic features with their geographic location. Most students have not travelled widely enough to easily associate the geology with maps and geography of a given area. For the regional geology course, the use of landsat imagery provides possibly the best method for making these associations.

Map Work

The key for students learning and appreciating the location of various geologic and physiographic features is having them physically put these features on to maps of their own. I require at the beginning of the course that each student purchase several outline maps of the U.S., in addition to a photo-atlas of the U.S. (Photo-Geographic International, 1975).

The outline maps are used in assignments requiring the drawing of physiographic regions, major drainages, altitudes and precipitation distribution. These are assigned in the first several weeks of the course when introduction and review are taking place. The students are allowed to obtain their information from any reference available to them in the library, in addition to their text. Both Natural Regions of the United States and Canada (Hurt, 1974) and Natural Regions of the United States (Pirkle and Yoho, 1977) have been used successfully as texts.

The photo-atlas is required in the latter three quarters of the course and is used for the term project. This photo-atlas provides composite landsat images at a scale of 1:1,000,000 over the entire U.S. including Alaska and Hawaii. As the geology of each physiographic province is discussed, the student is required to annotate significant geologic features such as structural basins, domes, folds, faults, hot springs, mining districts or unusual landforms directly onto the atlas. A list of these geologic features are handed to the student at the beginning of each assignment period (see Appendix for example assignment). The atlases are collected and graded three times during the semester. The student is allowed to use any published geologic map for reference; however, the two main sources are the Geologic map of the United States (King and Beckman, 1975) and the Geological Highway Map Series (AAPG, 1980) and these are posted on display boards in the department. In addition to the atlas, 35 mm slides of color composite landsat images mixed with ground scenes are shown once a week to further illustrate the provinces and the geology being studied.

The final annotated atlas, if done conscientiously, becomes an invaluable reference to the student, especially when making cross country treks via air or ground.

From these map exercises, students learn to appreciate landsat imagery, learn elementary skills in imagery reading and interpretation, in addition to making the association of geography, geology, maps and imagery.

Major Advantages of the Photo-Atlas (landsat composites)

1. Relatively inexpensive (~$10)

2. Scale (1:1,000,000) appropriate for annotating most major geologic features.

3. Atlas already marked with state boundaries, major rivers, lakes, cities and prominent land features (e.g. Cumberland plateaus, Niagara Falls).

4. Annotating the imagery helps the student associate geology with geographic setting.

Disadvantages of the Photo-Atlas

1. Binding of poor quality (sheets separate)

2. Many geologic features continue on separate pages; thus, the student may miss the over view appreciation.

Alternatives

1. Landsat composite of the U.S., published by the U.S. Soil Conversation Service, scale 1:5,000,000, 1 sheet ($15.00). This does not include Alaska or Hawaii, but does include state outlines.

2. National Geographic's Portrait USA (1976): Photomosaic of Landsat Imagery, scale 1:4,560,000, 1 sheet ($3.00). No state outlines are included and reproduction is not as clear as on the S.C.S. composite above.

3. Lobeck, A.K., 1941, Geologic Map of the United States: Maplewood, N.J., The Geographical Press, scale 1:5,000,000, 1 sheet ($2.00). This is good for general geology and it lacks enough detail so it allows the student to fill in the blanks.

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APPENDIX
EXAMPLE ASSIGNMENT

PHYSIOGRAPHIC REGIONS (GEOL 220)
PHOTO ATLAS ASSIGNMENT
Due in 3 weeks

A. Draw in the following province boundaries

1. Southern Rocky Mountains
2. Middle Rocky Mountains
3. Wyoming Basin
4. Northern Rocky Mountains
5. Colorado Plateau
6. Basin and Range
7. Great Plains

B. Locate with an arrow or shading or some other carefully designed method the following features:

1. Devil's Tower, WY
2. Nebraska sand hills with an arrow indicating wind direction
3. Wind Cave, SD
4. Great Sand Dunes National Monument, CO, with an arrow indicating wind direction
5. Grand Mesa, CO
6. Black Canyon of the Gunnison, CO
7. Hell's Half Acre, WY
8. Royal Gorge, CO
9. Spanish Peaks, CO
10. Florissant Lake Beds, CO
11. Southern limit of continental glaciation
12. Creede caldera
13. Silverton caldera

C. Locate and label properly (i.e., fold axes, plunge, faults properly labelled, etc.) the following structural features:

1. Black Hills Dome
2. Las Animas Arch, CO, KA
3. Llano Uplift, TX
4. Delaware Basin, TX
5. Anadarko Basin, TX, OK
6. Rock Springs Uplift, WY
7. Laramie Basin, WY
8. Blood Creek Syncline, MT
9. Eastern limit of disturbed melt, MT
10. Idaho batholith
11. San Juan Dome, CO
12. Piceance Basin, CO
13. Lewis overthrust

D. Add 10 additional geologic features of your choice and mark them with an asterisk.

CORSE-81

The 1981 Conference On Remote Sensing Education
May 18-22, 1981 Session No. 4D

Methods of Training the Graduate Level and Professional Geologist in Remote Sensing Technology

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Introduction

The transfer of remote sensing technology to the user community has traditionally been the responsibility of academic institutions. Remote sensing programs most often originate in the fields of geography, civil engineering, biology, range management, and, to a lesser extent, geology. Many schools, including junior colleges, offer a complete undergraduate (2 or 4 year) remote sensing program. These programs can produce excellent technicians, but, as in the case of the geological sciences, an inadequately prepared, discipline-oriented specialist frequently results.

Professional and/or graduate level geologists are better prepared to utilize remote sensing technology than their undergraduate counterparts or most scientists studying the earth's surface and subsurface features. As a result, a basic course in remote sensing has been developed to accommodate the needs for this part of the user community. This course, which has been offered as both a graduate-level semester course and a five-day short course, has been critiqued and well received by professionals.

Prerequisites

Most geologists are required to study the principles of structural geology, geomorphology, historical geology, stratigraphy, sedimentation, geophysics, field geology, and photointerpretation to complete the requirements for a B.S. Geology degree. Therefore, these people should be knowledgeable of the surface and subsurface geological processes and resulting landforms, the spatial configurations of rock structures, the different types of rock materials (lithologies), and the concept of geologic time. They should also know how to utilize the tools of aerial photographs and maps in geological and/or natural resource applications. If the geologist intends to utilize manual remote sensing methods, then it is suggested that additional coursework in geochemistry (weathering, mineral alterations, etc.), vegetation ecology (geobotanical correlations), and pedology be taken to broaden his/her perception of the earth's surficial aspect. This background, along with training in the basic principles of remote sensing, will adequately prepare the geologist to complete many of the tasks required in minerals, mineral fuels, water, and natural resources exploration, or to perform an engineering or environmental problem assessment.

Geologists intending to utilize the methods of computer image processing and analysis of remotely sensed data will need additional training in basic computer technology (FORTRAN or BASIC) and geostatistics. Remote sensing, like most other subdisciplines in geology, is quantitatively oriented. Therefore, an understanding of numerical manipulations is imperative.

To summarize, the prerequisites needed to become an adequately prepared geological remote sensing specialist include coursework in all of the previously discussed topics. It is recommended that the geologist specialize in at least one of the above fields in addition to remote sensing (geomorphology or hydrology, for example) to enhance his/her abilities and, therefore, his/her employability for government or private industry positions.

Introductory Remote Sensing Course Content

It is recommended that a minimum of two courses in remote sensing be taken by the aspiring geological remote sensing specialist: an introductory course involving the principles of remote sensing theory and the manual interpretation of remote sensing data, and a second course involving computer image processing and analysis of remotely sensed data. The geologist will understand, upon the completion of these two courses, how to generate new data configurations from the original information using the computer, and how to manually interpret any data output (which, in the author's opinion, is the most important aspect of utilizing the tool of remote sensing).

An introductory remote sensing course, which can be designed for either a semester or short course format, should cover the general topics of basic remote sensing theory, the theory of and data types relating to different remote sensing systems, an introduction to the basic concepts of computer image processing and analysis (to tease the student...), the characteristics of different data types, the development of procedures and methods for geological interpretations, the integration of all remote sensing data scales and data types in a given study, the integration of other data bases (geophysical and geochemical) into a remote sensing study, and geological remote sensing applications (Fig. 1a). The course should be divided into lectures

Figure 1a. Principles of Geological Remote Sensing Course Outline.

Course Outline:

I. Nature of EMR, Basic Remote Sensing Theory
II. Remote Sensing Systems and Data
  A. Photographic Systems
    Camera/Multiband Theory
    Aerial Photography
    Skylab and Manned Space Flight Photography
  B. Scanner Systems and Data
    LANDSAT imagery
    Thermal infrared imagery
    Microwave and RADAR imagery
III. Computer Image Processing and Analysis of Remotely Sensed Data
IV. Geological Remote Sensing Applications
  A. Integration into Mineral Exploration Programs
  B. Integration into Engineering and Environmental Programs
  C. Data Availability and Cost Benefit Analysis

Figure 1b. Principles of Geological Remote Sensing Laboratory.

LABORATORIES

Lab #	Topic
1	Nature of EMR Lab
2	Cameras/Multi-spectral Concept Lab
3	Flight Line Map/Cameras Lab
4	Flight Line Map/Cameras Lab
5	Scanners Lab/Thermal Infrared Data
6	Scanners Lab/Radar and Microwave Data
7	Flight Line Map/Scanners Lab
8	Scanners Lab/Landsat Exercise: Black Hills with Field Trip
9	Basic Photointerpretation/Geologic Photointerpretation
10	Base and Precious Metals Exploration Exercise/ Applications Lab
11	- development of geological interpretations
12	- integration of Skylab and high altitude aerial photographs (multi-scale)
13	Ground Water Exploration Exercise/Applications Lab
14	- integration of geophysical and geochemical data with remote sensing data
15	- usage of LANDSAT data
16	- development of geological interpretations

that present theory and background information, and laboratories that allow for "hands on" experience. It is recommended that laboratories comprise the major amount of course time to provide for a maximum amount of direct experience.

The initial lectures should present general remote sensing theory, and introduce the students to different remote sensing data types. Remote sensing theory, including the concepts of electromagnetic radiation (EMR) and the energy path, is fundamental to the geologist's understanding of a remote sensing "measurement." The theory of different remote sensing systems, and the resulting data types, show the geologist the diversity of remote sensing options available, the different types of information that can be obtained relating to a specific problem, and the advantages or disadvantages of each given data type. Both photographic and scanner systems and their corresponding data types should be discussed. The theory and concepts of thematic mappers, multispectral scanners (LANDSAT, specifically), and side-looking, synthetic aperature RADAR would be discussed in the "scanners" category.

The basic concepts of computer image processing and analysis are introduced to demonstrate new methods of data extraction and presentation. Finally, the last series of lectures should present such topics as general remote sensing applications in geology, the integration of different data types and data bases (geophysical, geochemical, and multiple remote sensing bases), cost-benefit analyses, data availability, and integration of remote sensing methods into exploration programs.

The laboratories should compliment the course lectures, and should provide the student with "hands on" experience regarding different data types, geological applications, and the development of geological interpretations using a multi-temporal, multi-spectral, and multi-data approach (Fig. 1b). The first series of labs should familiarize the geologist with camera and scanner technology, aerial photographs, and thermal infrared, RADAR, and LANDSAT imagery. The second group of labs should integrate, using two or three different exercises, the various remote sensing data types and scales, and collateral geophysical and geochemical data. These labs should give the geologist experience in utilizing the methods of manual interpretation in developing geological models for given applications. The topics of exploration (minerals, oil and gas, water) and engineering and environmental problems in geology are commonly used.

Visual Aids

In the lecture situation, numerous slides (many of which are available through the EROS Data Center) prove to be an easy method of conveying information. Occasionally, the usage of a blackboard and an overhead projector is necessary.

It is costly and necessary to order a variety of data types (high altitude and Skylab photography; RADAR, thermal IR, and LANDSAT images), numerous educational materials (overlays-MYLAR is best, marking pens, straight edge, tape, scissors, etc.), alternate data sets (geophysical and geochemical information) and tensor lights for the laboratories. A lab manual, if available, is most helpful.

Summary

The prerequisites for a Principles of Geological Remote Sensing course should ideally include the basic courses of structural geology, geomorphology, historical geology, stratigraphy, sedimentation, geophysics, field geology, photointerpretation, geochemistry, vegetation ecology and pedology. The prerequisites for advanced remote sensing courses include computer programming and geostatistics. Therefore, a geologist who intends on becoming a remote sensing specialist will probably complete the necessary background during the pursuit of a graduate degree or through post-B.S. work experience.

The introductory course in geological remote sensing should stress the general topics of basic remote sensing theory, the theory and data types relating to different remote sensing systems, an introduction to the basic concepts of computer image processing and analysis, the characteristics of different data types, the development of methods for geological interpretations, the integration of all scales and data types of remote sensing in a given study, the integration of other data bases (geophysical and geochemical) into a remote sensing study, and geological remote sensing applications. The laboratories should stress "hands on" experience to reinforce the concepts and procedures presented in the lecture. The geologist should then be encouraged to pursue a second course in computer image processing and analysis of remotely sensed data.

Discussion Topics

I. Teaching aids, field projects

Many ideas were exchanged on means for providing students with effective and yet inexpensive imagery and materials for classroom and laboratory use. The importance of coordinating field trips with class lectures and lab projects was discussed.

II. Graduate-level Programs

The following list of universities with graduate geology remote sensing programs was compiled (faculty contacts in parenthesis):

California Institute of Technology - Cal Tech (JPL-Geotz)
Colorado School of Mines (Lee)
Dartmouth College
Indiana State University (Howe)
Old Dominion (Drake)
Penn State University (Gold)
Purdue University (Levandowski)
San Diego State University (Finch)
South Dakota School of Mines & Technology - S.D. Tech (Kolm)
Stanford University (Ron Lyon)
University of Arizona (Slater)
University of Arkansas (McDonald)
UCLA (Sabins)
UC Santa Barbara (Estes)
University of Hawaii (McCord)
University of Idaho (Bill Hall)
University of Iowa (Hoppin)
University of Massachusetts (Wise)
University of Michigan (Eschman)
University of Utah (Ridd, Lattman)
University of Washington (J. Adams)
University of Wyoming (Marrs)
University of Wisconsin (Kiefer)

III. Sources of imagery

Remote Sensing Enterprises P.O. Box 2893 LaHabra, CA 90631	Remote Sensing slide sets & guide; Lab Manual with Instructor's Key
EROS	Complete slide coverage (LANDSAT) of United States
GE Photographic Laboratory Beltsville, MD (Hertzel Ave.)	photo mosaic for each state
JPL, Pasadena, CA (Att'n.: John Ford)	"The Best of SEASAT"

National Space Science Data Center Goddard Space Flight Center Greenbelt, MD	Thermal IR (HCMM)
NOAA	Seasat images, catalogs
Rome A.F.B. (Air Development Center) (Att'n.: Public Affairs Officer)	
W.H. Freeman Publ.	John Shelton's slide sets

IV. Digital Processing

Harvey Wagner, EROS, informed the group about the "under $20,000" processor system under development at the data center. Harvey will see that attendees of the geology discussion session receive "LANSAT Data User Notes" from EROS.

V. Remote sensing course emphasis

A general discussion was held on the need for and extent of computer training for students in Remote Sensing.

VI. Interaction, communication with other departments, administration, the public

Strategies for stimulating communications regarding remote sensing education and applications:

a) broaden student experience
 - line up guest lecturers (professors, graduate students, professionals from the private sector)

b) broaden university-wide interest and cooperation
 - emphasize interdisciplinary applications
 - extend personal invitations to colleagues across campus
 - provide images

c) broaden the awareness of the administration
 - keep them informed of developments
 - extend personal invitations
 - provide images

d) broaden the awareness of the general public
 - give presentations to service clubs, schools (K-12 & JC)
 - provide images

VII. Background and prerequisites for a Remote Sensing course

Strategies for preparing students for continued studies in remote sensing:

a) stress the importance of physics, math, and computer science to the students

b) challenge the student to "think geology" (or other appropriate discipline) as they take support courses from other departments (i.e., consider applications of material from these courses in their own field)

c) stress manipulative skills (materials and equipment handling)

d) a "back door" approach can be effective (e.g., teach them the needed principles of math or physics when they don't know they're getting it!)

e) an introduction to principles in lower-level courses is valuable even though the principles have to be covered again in upper-level courses

f) teach enough to make the student literate in the subject

VIII. GEOSAT Test Case Studies

The GEOSAT Committee and NASA are concluding Phase I of the Test Case Program. It is important that educators have access to the published results of the studies. Sabins agreed to interface with NASA and GEOSAT to insure wide distribution of results.

IX. Future of CORSE

The group discussed the importance of continuing the CORSE series because of the opportunities which it provides:

- to broaden one's viewpoint
- to learn new techniques/applications
- to make valuable personal contacts
- to learn sources of information

It was recommended that each attendee write a letter (on a departmental letterhead) to Shirley Davis of LARS providing her with an evaluation of CORSE-81 and, hopefully, an expression of a desire to continue the series.

Participants in Geology Discussion

ARÑOLD, Robert H.
BLAIR, Robert W., Jr.
BROPHY, David M.
CANNON, Phil
CORLISS, Bruce C.
DECAPRARIIS, Pascal
DODSON, Russ
ENGELBRECHT, Kenneth W.
GREEN, Jerry E.
GUNTHER, Fred J.
HOPPIN, Richard A.
HOWE, Bob
KIM, Soon T.
KIND, Tom
KOLM, Kenneth E.
KRIZAN, Don
LEUNG, Samuel S.
LINDENLAUB, John
MCCORD, Tom
O'BRIEN, Neal R.
RIECK, Richard
SABINS, Floyd
SHORT, Nick
WAGNER, Harvey
WERNER, Eberhard

Session 4-E

Interdisciplinary Programs

Highlights:

Under the guidance of session chairman Philip Swain of Purdue University, the discussion session on Interdisciplinary Programs included four papers, all of which are printed on the following pages. Notes from the ensuing discussions follow. Session reporter was Jim Tilton, Purdue University.

Additional comments by P. Murtha:- When seeking to effectively teach remote sensing, one must start with the idea of interdisciplinary cooperation. When one sees industry offering several short courses on a topic, one should suspect the university community is not doing a proper job. This was the case in the mid-1970's when UBC had courses in remote sensing scattered among various departments with no coordinator or sharing between the departments.

In 1977 remote sensing activities were consolidated under the UBC Council on Remote Sensing, as described in paper. Remote sensing programs at UBC work because of interdepartmental cooperation. UBC had 30 remote sensing graduate students the past year and graduated 3 M.S. and 2 Ph.D. students.

Discussion following Dr. Murtha's Paper:

Penn State has a similar interdisciplinary program, but the computer science people aren't interested in it. At UBC, the remote sensing people had the data and application that the computer science people wanted. At Penn State no one in Computer Science seems to be interested in image analysis.

At the University of Massachusetts the experience was that it was easier to get graduate students interested in remote sensing. The grad students then pressured (or influenced) the faculty towards getting involved in remote sensing. Also, if the faculty can get equipment through remote sensing work, they will get interested.

Cooperation also depends on the personalities involved. There is a need for having people interested in applications, but also need the theoretical people. Many theoreticians are looking for a project they can hang their theory on.

Additional Comments by W. Meyers:

Penn State has an interdisciplinary program in remote sensing. Remote sensing is considered to be a subsegment of the science of providing information. Penn State has a senior level course on remote sensing (air photo & quantitative analysis) and a graduate level course on computer analysis. It is generally found to be easy to relate to students from various disciplines by relating remote sensing to their disciplines.

It is hard to make a discipline specialist into a good statistical analyst for, say, Landsat data. Discipline people generally won't use the more sophisticated information extraction techniques unless heavily trained in statistics. In order for the more sophisticated techniques to be used more fully, remote sensing specialists must be used in conjunction with discipline specialists. Don't train discipline people to know all remote sensing; train remote sensing specialists to know enough of the disciplines so that they can interrelate with them. The GIS can be used as a bridge point. One should link Landsat analysis with the GIS. Make the Geo-unit identifier look like another Landsat channel. Output percent classification per Geo-unit from Landsat.

Discussion following Dr. Chung's presentation:

Excessive use of jargon often seems to be used in order to confuse outsiders so we won't be bothered by them.

We must be very careful to avoid jargon when talking with non-remote sensing people.

Quantitative jarjon in the social sciences is often worse then remote sensing jargon. We need to translate between jargons, but we should not necessarily adopt another discipline's jargon.

Discussion following Dr. Welch's paper:

We should call "ground truth" "terrain reference data". One doesn't always need ground truth from actual field work. Other information like government reports and old aerial photographs can be used to check results.

In Georgia soft money (outside funding) was not used to build up the remote sensing program. They have concentrated on <u>teaching</u> remote sensing. Georgia's experience has shown Remote Sensing Educational and research programs <u>can be</u> successfully developed based on internal support - take it slow, <u>build</u> steadily.

One must be sure to have someone to maintain any equipment secured.

At UBC joint proposals including various departments were the key to getting funding for equipment.

At Georgia aerial photography is taught first so the students will appreciate it before they are exposed to quantitative work with Landsat data.

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REMOTE SENSING EDUCATION AT THE UNIVERSITY OF BRITISH COLUMBIA

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INTRODUCTION

The University of British Columbia's (UBC) interdisciplinary graduate program in remote sensing was approved by the UBC Board of Governors in June of 1977 under the Universities' Council of British Columbia "Programs of excellence". Basic funding was approved for additional Faculty, technical suport staff and an image analysis system. The initial proposal, put forward by four faculty members in five departments (there was one joint appointment) proposed to develop and complement a program which offered graduate degrees in remote sensing and to expand the facilities available to the University through:

(a) integration of programs;

(b) organization of facilities for use by an increased number of graduate students, and

(c) counting course-work taken in cooperating departments involved in remote sensing as part of the required course of the student's chosen department.

When the proposal was put forward, a need was recognized for individuals qualified at the graduate level in remote sensing; industry had sponsored short-courses in remote sensing to offer opportunities for professional up-grading, and the Gaudry Report on the State of Research and Research Funding in British Columbia had called for expansion of research in natural resource-related fields. Nealy (1977) had indicated almost total absence of interdisciplinary graduate programs in remote sensing in Canadian Universities, especially those programs with representation in fields as important or diverse as civil engineering, computer science, forestry, geography, and soil science.

In 1977, 22 units (credit hours) of course work existed in remotes sensing in the five departments (civil engineering, computer science, forestry, geography, and soil science) at the senior undergraduate and graduate level. Graduate students were required to enter discipline departments within the Graduate Faculty when doing graduate studies, and each Department had its own particular set of requirements for completion of degrees at either the Master's or Ph.D. level.

The expected results of the program were to provide suitably qualified candidates for remote sensing positions in industry, etc.; to provide better University training for students in the natural resources field, and to show greater visibility to the community of a unique and viable remote sensing program.

CURRENT STATUS

The interdisciplinary program in remote sensing is currently administered through the Council on Remote Sensing with nine Faculty members representing nine Departments and varied remote sensing interest (Table 1).

Studies in remote sensing leading to either Master's or Ph.D. in the nine discipline Departments are coordinated by the Council. However, students enter the remote sensing program by admission as a Master's or Ph.D. candidate in one of the Departments, and must complete the degree requirements of that Department, except as provided for in the original proposal (item c).

The discipline Department and the student's committee chairman are selected from the Department which represents the students primary field of interest. Students are encouraged to seek representation on their committee from other University Departments. In consultation with their committee, specialized programs of study are developed for the Masters or Ph.D. candidate in any aspect of remote sensing, or in any application of remote sensing technology. There is a philosphical division which separates

Table 1. The University of British Columbia Council on Remote Sensing.

Faculty Member	Department(s)	Remote Sensing Specialization
P.A. Murtha* (Chairman)	Forestry, Soil Science	Photo interpretation - vegetation and terrain analysis
H. Bell	Civil Engineering	Engineering photo interpretation
Wm. Emery*	Oceanography, Physics	Physical oceanography
A.L. Farley	Geography	Cartography
M. Ito	Electrical Engineering	Signal processing
A.K. Mackworth	Computer Science	Artificial intelligence - scene analysis
H. Schreier	Soil Science	Land classification
G. Walker	Geophysics and Astronomy	Sensor development
R.S. Woodham*	Forestry, Computer Science	Artificial intelligence - image analysis

* Joint appointment - may take graduate students in either department.

studies in remote sensing, versus studies using remote sensing. Thus, specialized programs are tailored to meet the student's needs and interests and can range from theoretical development of remote sensing technology (including sensor development, modelling, and computer analysis, i.e. Leckie, 1980; Little 1980) to specialized application of remote sensing in resource analysis, (including vegetation damage (Hall 1981), land classification, land-use analysis (Allan 1980)).

There are presently about 31 units (credit hours) of course work in remote sensing and remote sensing related courses in the departments affiliated with the Council on Remote Sensing. The courses are listed in Appendix I. It is noted that many courses are cross-listed in order to increase visibility within the calendar.

Research is funded by a wide variety of granting agencies, and by research contracts with industrial and government organizations. Remote sensing research facilities are housed in the various associated Departments and include a wide range of modern equipment which is continually being up-dated. [For example a high speed communication link was installed in 1980 between the image analysis system and the main university computer that transfers the data at a rate of a mega-bit per second. It replaced a 9600 baud line.] Students within the remote sensing program have open-access to remote sensing facilities in the other Departments, but the primary path leads to the Laboratory for Computational Vision where a Comtal Vision One color image processing and display system has a direct link with a HP-21MX and the high speed link with an Amdahl 470/V8.

At the present time there are about 20 graduate students involved in remote sensing studies, with the greatest concentration in computer science and forestry. Since a number of the courses are at the senior undergraduate level, many undergraduates take advantage of the courses and elect to study remote sensing as an area of concentration in their major field of study, or add a remote sensing subject to round out their selection of electives.

Generally, the original purposes of the interdisciplinary graduate program in remote sensing have been obtained. Integration across different departments have been achieved and there is inter-department cooperation and mixing among the graduate students. Facilities are more efficiently used, and there has been a marked increase in graduate studies in remote sensing. Successful candidates have rapidly entered the work force with industry, government, or on their own as a private consultant.

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Leckie, D.G. 1980. Development of a right-time evolving model for remote sensing thermal inertia mapping. Ph.D. Thesis, Dept. Soil Science, UBC., Vancouver, B.C. 246 p.

Little, J. 1980. Automatic rectification of LANDSAT images using features derived from digital terrain models. M.Sc. Thesis, Dept. Computer Science, UBC., Vancouver, B.C.

Nealy, L.D. 1977. Remote sensing/photogrammetry education in the United States and Canada. Photogram. Eng. and Remote Sens. 43(3):259-284.

APPENDIX I

Courses in and applicable to studies in Remote Sensing, Graduate level courses are in the 500 series.

Department and Course No.	Title
Astronomy 421	Astronomical and Astrophysical Measurements
Astronomy 431	Astronomical Laboratory
Civil Engineering 453	Elementary Photogrammetry
Civil Engineering 456	Photogrammetric Surveying
Civil Engineering 576	Civil Engineering Uses of Aerial Photographs
Computer Science 414	Introduction to Computer Graphics
Computer Science 435	Same as Forestry 435
Computer Science 502	Artificial Intelligence I
Computer Science 514	Advanced Computer Graphics
Computer Science 522	Artificial Intelligence II
Electrical Engineering 466	Digital Signal Processing Systems
Electrical Engineering 575	Signal and Image Processing
Forestry 422	Land Classification
Forestry 435	Computer-based Image analysis for Forest Inventory Systems
Forestry 442	Photo Interpretation of Forest Lands
Forestry 443	Remote Sensing in Forestry and Agriculture
Forestry 542	Advanced Studies in Photogrammetry
Forestry 543	Selected Topics in Remote Sensing
Geography 370	Air Photo Analysis
Geography 372	Cartography
Geography 470	Remote Sensing in Geographic Enquiry
Geology 305	Field Methods
Soil Science 417	Same as Forestry 422
Soil Science 442	Same as Forestry 442
Soil Science 443	Same as Forestry 443

NASA

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TOWARD MULTIDISCIPLINARY USE OF LANDSAT: INTERFACING COMPUTERIZED LANDSAT ANALYSIS SYSTEMS WITH GEOGRAPHIC INFORMATION SYSTEMS

Wayne L. Myers
The Pennsylvania State University

Several centers for remote sensing research and training now offer short courses designed to acquaint the uninitiated with computer processing of Landsat data, and hopefully to impress them with a host of potential applications in their respective fields of endeavor. The participants usually come away duly impressed with the "space age" nature of the technology, but rather uncertain as to just how it can be applied to their routine activities. Color displays and computer classification maps may be interesting, but seldom appear to relate directly to the information base that the trainee regularly uses. Most successful "applications" apparently still arise from demonstration projects carried out by remote sensing specialists.

The major difficulty with these technology transfer efforts seems to lie in the attempt to sell Landsat as a relatively independent data source, apart from the need for some "training sets" for supervised classification. Even the major research thrusts are directed mostly toward making the Landsat systems sophisticated on a stand-alone basis. Multi-temporal and multi-sensor analyses are typically implemented through single pass processing of merged data sets containing a multitude of "channels." The fact of the matter is that Landsat seldom constitutes an adequate and independent data source for real-life situations. It is time that we stopped trying so hard to make the rest of the information world revolve around Landsat, and instead begin treating Landsat as a means of augmenting data bases containing information from many other sources. Perhaps then the potential users will be better able to see how Landsat can fill some gaps in existing data bases that otherwise serve the decision makers of the world reasonably well.

Entirely apart from Landsat, there are a number of good reasons for computerizing location specific data bases containing multiple layers of information. Therefore, it seems reasonable to assume that the growing trend toward use of some sort of computerized geographic information system will continue. Likewise, it is appropriate to explore augmenting data bases via Landsat under the assumption that a computerized geographic information system (GIS) will host the data base. If the potential users are not yet into computerized information systems, then they should be introduced to a simple GIS along with their exposure to Landsat. Although scarcely worthy of the designation GIS, something as simple as SYMAP can serve to demonstrate the possibilities.

The need, then, is to have a relatively simple way of incorporating the results of Landsat analyses into computerized geographic information systems as additional layers of information. A desirable feature of the interface is that it should not require substantial alterations in either the Landsat processing system or the GIS. The ZONAL (ZONation ALgorithms) approach being developed in the ORSER group at Penn State University appears to satisfy all of these criteria. The first version (designated ZONAL1) described in this paper provides for entering classification results produced by the ORSER remote sensing analysis system into cell-oriented geographic information systems. However, substituting another Landsat analysis package for the ORSER system is simply a matter of changing format. Augmenting information systems that utilize polygons and arcs as geounits is somewhat more complicated, but conceptually straightforward. Interfaces for the latter types of geounits will be implemented in subsequent versions of ZONAL.

The essential task in the Landsat-GIS interface is to summarize the results of the Landsat classification over the same cells that serve as geographic referencing units for the GIS, and then to output these summaries on a cell-by-cell basis in a form that is readable by the input routines of the GIS.

A prerequisite for accomplishing this task is to geometrically correct and register the Landsat data to the coordinate grid used on the GIS. Thus, use of the ZONAL interface does assume sufficient sophistication in the Landsat processing system to accomplish this geometric correction and registration. The ORSER system has this capability, as do also most of the better known Landsat analysis systems.

The ZONAL interface for cell-oriented systems consists of two primary programs. The first (called PIXCEL) simulates the action of a scanner. It scans the grid of cells and outputs a "channel" of "pixels." Instead of reflectance values, however, each "pixel" simply contains the identifier of the cell in which the center of the "pixel" is located. These "pixels" are written on a computer tape, disk file, or deck of punched cards. Options are available to accommodate any chosen size of rectangular referencing cell as well as any rectangular "pixel."

Input to the second program (called CELSUM) consists of this file of pixelized cells along with the results of a pixel-by-pixel classification of the scene produced by the Landsat analysis system. CELSUM matches these two files on a pixel-by-pixel basis, accumulating over each cell to obtain the percentage of the pixels in the cell that belong to specified categories as determined by the Landsat classification. The output file contains a cell-by-cell summary formatted according to the requirements of the host GIS.

A simple example of the ZONAL1 approach is given in Figures 1 and 2 and Table 1. Figure 1 depicts a 2×3 grid of 25-acre cells containing Landsat classification results for 1-acre pixels (squared). Figure 2 shows the corresponding pixelization of cell identifiers as generated by PIXCEL. Table 1 contains the cell-by-cell tabulation of classification results as developed by CELSUM.

Cross-correlation of the Landsat layer with the other layers residing in the data base is accomplished with the analysis and display facilities of the GIS. Thus, the information extracted from Landsat can be used for overlays, updating, change detection, etc., without any further recourse to the Landsat analysis system. Furthermore, pixelization of cells is a one-time operation that need not be repeated for later CELSUM runs on additional Landsat layers as long as the cellular referencing units are not altered.

The ZONAL-GIS interface offers the additional advantage that the user need not become directly involved in the Landsat analysis. A contract can be arranged for a given Landsat analysis, with the deliverable product being a cell summary file ready for loading into the data base. Subsequent analysis is then entirely at the discretion of the user, with no further need for involvement on the part of the Landsat service center. The user retains sole responsibility for and control over the data base--which is as it should be.

+	+	+	+	+	+	+	+	-	-	-	-	-	-	-
+	+	+	+	+	+	-	-	-	-	-	-	-		
+	+	+	+	+	-	-	-	-	-	-				
+	+	+	+	-	-	-	-	-	-					
+	+	+	+	-	-	-	-	-						
+	+	+	+	-	-	-	-							
+	+	+	+	-	-	-	-							
+	+	+	-	-	-	-								
+	+	+	-	-	-	-								
+	+	-	-	-	-	-								

Figure 1. Two-by-three grid of 25-acre cells with Landsat classification results based on squared 1-acre pixels. (+ = forested; - = brushland; blank = grassland)

1	1	1	1	1	2	2	2	2	2	3	3	3	3	3
1	1	1	1	1	2	2	2	2	2	3	3	3	3	3
1	1	1	1	1	2	2	2	2	2	3	3	3	3	3
1	1	1	1	1	2	2	2	2	2	3	3	3	3	3
1	1	1	1	1	2	2	2	2	2	3	3	3	3	3
4	4	4	4	4	5	5	5	5	5	6	6	6	6	6
4	4	4	4	4	5	5	5	5	5	6	6	6	6	6
4	4	4	4	4	5	5	5	5	5	6	6	6	6	6
4	4	4	4	4	5	5	5	5	5	6	6	6	6	6
4	4	4	4	4	5	5	5	5	5	6	6	6	6	6

Figure 2. Pixelized cell identifiers corresponding to the grid in Figure 1.

Table 1. Cell-by-cell tabulation of percent coverage by feature category.

Cell #	% Forest	% Brushland	% Grassland
1	92	8	0
2	16	80	4
3	0	36	64
4	64	36	0
5	0	48	52
6	0	0	100

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COMMUNICATING REMOTE SENSING CONCEPTS IN AN INTERDISCIPLINARY ENVIRONMENT

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Although remote sensing is currently multidisciplinary in its applications, many of its terms come from the engineering sciences, particularly from the field of pattern recognition. Scholars from non-engineering fields such as the social sciences, botany, and biology, may experience initial difficulty with remote sensing terminology, even though parallel concepts exist in their own fields.

This paper will identify some parallel concepts and terminologies from neighboring fields, which might enhance the understanding of remote sensing concepts in an interdisciplinary situation; and briefly explore some feedbacks which this analogue strategy might have on remote sensing itself.

Supervised vs. Unsupervised Classification

As used in remote sensing the differentiating characteristic between these terms seems to be whether the classes are known or selected a priori or not. If the classes are selected a priori, then the classification process is labelled "supervised," and if not, it is labelled "unsupervised." Because there has been a quantitative revolution in most of the social sciences (including history) during the past decade, most academic social scientists would recognize the parallels of the problem of assignment to known classes as a discriminant analysis type problem, and the emergence of classes without prior identification as a multivariate data reduction type process. Actually, one could make an argument that they are both "supervised," one being more algorithmically supervised and the other having more direct human supervision.

Once the unfamiliar label is clarified, however, botanists and biologists (Sneath & Sokal, 1973) familiar with numerical taxonomy, and geographers (Berry & Marble, 1968) familiar with numerical regionalization, would readily grasp the concepts. Psychologists (Thurstone, 1931; Hotelling, 1933; Tryon, 1939; Stephenson, 1953) with their R-mode and Q-mode (and others) analyses, dependent on whether the variables are grouped, or the data matrix is transposed and the entities or cases grouped directly; and sociologists and urban scholars (Berry & Horton, 1970) with social area analysis and factorial ecologies, would follow whats going on. Psychologists, of course, are to be credited with the pioneer developments in cluster analysis and factor analysis.

This kind of analogue thinking raises the possibility of the application of some techniques commonly used in those fields to the situation labelled supervised classification in remote sensing. Thiessen polygons, Location-allocation methods, and Linear programming algorithms, particularly the Transportation model, seem applicable in some situations where for instance the parallelopiped model is used. For example, the school districting problem of assigning students to schools with the constraint of minimizing distance travelled seems very similar to the allocation of unknown pixels to known prototype pixel classes on the basis of distance minimization in a two or n-dimensional feature space.

With respect to unsupervised classification, feedback possibilities based on practices in neighboring fields, include (a) higher order cluster analysis for reclassifying or aggregating to larger macro classes in the presence of too many subclasses; and (b) application of more than one data compression algorithm to the data set as a means of validation. Classes that occur repeatedly despite varying algorithms are given greater validity.

Topographic Elevation as Ancillary Data in Forestry Classification

Economists (Suits, 1957) would readily perceive the issues involved if the parallelism of the use of elevation data in forestry classification and dummy variable analysis as used with regression models is pointed out. Of course, "dummy variable" as a label also carries no intrinsic clue to the meaning of the concept either. One feedback is that other key ancillary information may be brought in as dummy variables in a simple nominal scale or presence-absence measurement mode to enhance the separability of the classification of the feature of interest.

Density Slicing and Contrast Stretching

Every now and then, I am asked, "What is density slicing"? An analogue process is that of class interval selection in cartography. Similarly, contrast stretching has its analogue in concepts like logarithmic and other transformation of data as commonly done in many fields. Kimerling (1976) has explored the similarities between cartography and remote sensing.

Contextual Analysis

My own experience can be used to illuminate this concept. While attending my first Remote Sensing Symposium last year, I was looking for a session or papers dealing explicitly with analysis of the spatial properties such as texture and neighborhood functions of a scene in a digital mode. I by-passed a session on Contextual Analysis because I did not at first recognize the spatial implications of the label. Some feedbacks may be obtained from the current work being done on Spatial autocorrelation (the spatial analogue of the more well-known time series autocorrelation) and space-time series in quantitative geography.

Scene Complexity

A senior scholar in remote sensing, Professor Landgrebe (1978) writes:

> The scene is the portion of the system which provides us with the greatest challenge...It is the only portion of the system not under design or operational control. However, and much more significantly, it is by far the most dynamic and complex portion of the system. There are so many different classes of materials which are found on the earth's surface, and they can be found with so many subtle and not-so-subtle variations due to such a large number of factors, that one must strive for a very knowledgeable orderliness and discipline to see them in their proper interrelationship. (p. 339)

Members of the new interdisciplinary field of Regional Science would appreciate this complexity. However, its founder, the economist Walter Isard (1960) indicated that although it "focuses on spaces and systems of spaces, regions and systems of regions, locations and systems of location... regional science concentrates its attention upon human behavior and institutions; and, unlike geography, gives only incidental consideration to physical and biological processes *per se*" (pp. 9-10).

This minimization of the physical and biological by Isard weakens the substance analogy with remote sensing, but the parallelism remains.

The analogue of scene complexity is best illustrated by the discipline of Geography, both in substance content and in parallelism of form. The leading philosopher of geography, Richard Hartshorne (1959) writes:

> In geography, in contrast the interest is focused from the start on the existing integration of diverse phenomena, which, by their existence, determine the variable character of area. (p. 32)
>
> The earth is unique to our knowledge as an object which consists of integrations formed by a great diversity of inanimate, biological, and social phenomena, varying in significant interrelations from place to place. The goal of geography, the comprehension of the earth surface involves therefore the analysis and synthesis of integrations composed of interrelated phenomena of the greatest degree of heterogeneity of perhaps any field of science. (p. 35)

Feedbacks on the Nature and Scope of Remote Sensing

The philosopher Immanuel Kant viewed all kinds of knowledge as (Hartshorne, 1939; Estes, Jensen & Simonett, 1980) grouped by:

1) Kinds of objects or phenomena study
2) Relationships through time
3) Association in space

Their contemporary category equivalent would be Thematic, Temporal and Spatial.

If, as Estes, Jensen, and Simonett (1980) maintain, Remote Sensing "can almost be viewed as a discipline in and of itself" (p. 73), then this incipient multispectral, multi-temporal and spatial discipline may benefit from looking at itself from the perspectives of those disciplines which focus on "all kinds of things in all kinds of combinations...regardless of the classification of the phenomena by kind" (Hartshorne, 1959, p. 34). These would be the historical sciences and the spatial sciences such as Geography and Regional Science.

Quite logically most Remote Sensing applications to date have been on Thematic or topical applications, focusing on a specific kind of phenomena and benefitting from the processes and theories of the systematic disciplines involved. In this mode of thought, the information of interest is viewed as signals and the rest as noise. Even the apparent multi-theme contemporary Geographical Information Systems seem more thematic because of their limited topical objective and contents.

With the prospect of increasing scene resolution, the time is ripe for practitioners of remote sensing to dip into the "noise" sector of the signal/noise scene and confront the challenge of the analysis and synthesis of this integration of phenomena of the greatest heterogeneity.

This challenge will call for interdisciplinary perspectives of the highest order.

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The 1981 Conference On Remote Sensing Education
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REMOTE SENSING EDUCATION FOR THE EARTH SCIENCES: THE UNIVERSITY OF GEORGIA EXPERIENCE

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INTRODUCTION

The remote sensing program of the Department of Geography, University of Georgia, includes several courses (Table 1), and is designed to fulfill the following objectives:

1. Provide sufficient breadth of course work to enable students interested in the earth sciences, particularly geography, geology, and forestry, to obtain a foundation knowledge in remote sensing methodology and applications.
2. Provide a balance between theory and practice in all courses, with orientations towards the requirements of earth scientists.
3. Provide adequate research opportunities for graduate students pursuing the M.A. and/or Ph.D. degrees.
4. Provide an advanced research capability for both faculty and students.

A student interested in remote sensing (defined in this paper to include both image interpretation and photogrammetry) is encouraged to enroll in one or more of the courses listed in Table 1 and to consider additional work in computer programming, quantitative methods, cartography and geographic field methods.

Instruction in remote sensing techniques and applications requires adequate space and at present, air photo interpretation practicals are conducted in two adjacent laboratories with seating capacities of 20 students each. A photogrammetric laboratory and a remote sensing laboratory designed to support research activities are utilized for the more advanced courses, and several types of equipment are available for both instruction and research (Table 2). Other facilities which support remote sensing activities include a departmental darkroom, the University libraries, the University Cartographic Service Laboratory (housed adjacent to the photogrammetry laboratory), and the University computer center with IBM 370/158 and CDC Cyber 74 systems.

COURSE OBJECTIVES AND CONTENT

Use and Interpretation of Aerial Photographs--GGY 420/620

Originally developed as a service course, Use and Interpretation of Aerial Photographs is designed to acquaint students with techniques for the analysis of aerial photographs, including simple procedures for the extraction of positional data and preparation of base maps. Classes consist of 20 to 30 undergraduate and graduate students from geography, geology, forestry and environmental design and meet in one-hour lecture sessions three times per week and for two-hour laboratory periods twice per week. Lectures stress the theoretical aspects of scale, geometry, cameras, film-filter combinations, analysis and mapping techniques, and provide an introduction to the satellite, thermal infrared and radar remote sensing systems considered in the more advanced courses. Laboratory exercises are arranged to complement the lectures, and, for the first two-thirds of each quarter, practicals are restricted to basic exercises concerned with the determination of scales, heights, distances, areas and with the preparation of planimetric maps. During the last four weeks of the course, however, the students are organized by disciplines into groups of 2 to 4 students. Each group is assigned a comprehensive practical which requires the integration of knowledge of a discipline with investigative procedures and photo-analysis skills to prepare a report and maps on a given subject/geographical area. Typical project assignments include: 1) inventory of forest tracts owned by the University of Georgia; 2) determination of urban land use and land use changes for Athens during the period 1944-1980; or 3) tracing the development of a glacial landscape in Alaska or Iceland over a 20-year period. All of these projects involve the use of sequential aerial photographs recorded with different film-filter combinations.

Advanced Photogrammetry--GGY 422/622

Advanced Photogrammetry is offered to classes of 5 to 10 geography graduate and senior undergraduate students interested in obtaining sufficient theoretical and practical background to tackle earth science projects which require accurate measurements of objects recorded on aerial photographs and satellite images. Emphasis is on measurement by analogue and analytical methods rather than on interpretation. Lectures occupy approximately three hours each week and there are associated laboratory periods. The lectures are an extension of subjects covered in the prerequisite 420/620 course, whereas the laboratory practicals consist of four exercises conducted on an individual basis. These exercises include:

1. Orientation of a stereomodel and plotting a topographic map with either the Kelsh or multiplex plotter.
2. Preparation of a planimetric map of an urban area from a satellite (Skylab) photograph with the Bausch and Lomb Zoom Transfer Scope.

3. Preparation of a topographic map by simple methods. This exercise integrates the use of radial line methods, mirror stereoscope and parallax bar, a computer program to derive absolute elevations from parallax bar observations and a Saltzman overhead projector to transfer planimetric detail.
4. Preparation of a flight plan for high-altitude aerial photography of Georgia suitable for topographic and land-use mapping to defined accuracy standards.

In addition to the lecture materials and laboratory exercises, students are asked to prepare a paper on a particular aspect of photogrammetry (e.g., "Digital Mapping Techniques for Earth Scientists") and to review the literature concerned with photogrammetric applications in the earth sciences. In the latter case, 300-word summaries of 5 to 10 recent articles are required. At the completion of the course a field trip is scheduled to the Office of Surveys and Aerial Mapping, Georgia Department of Transportation, to view the activities and equipment of a modern photogrammetric operation. As few earth science departments provide instruction in photogrammetry, students with this background have a competitive edge in the job market.

Remote Sensing of Environment--GGY 423/623

In this course emphasis is placed on new and advanced aspects of remote sensing beginning with lectures on fundamental properties of the electromagnetic spectrum, photometry and radiometry, and proceeding to multispectral, satellite, thermal infrared and radar imaging systems. Classes normally draw 15 to 20 graduate and undergraduate students from geography, geology, forestry, ecology and agronomy, and meet daily for one-hour lecture sessions. Laboratory exercises are assigned as "homework" projects. Students are provided with up-to-date reading lists for each topic and are required to prepare a term paper on a remote sensing system and to assess its applications within a specific branch of the earth sciences. As a supplement to the normal lecture sessions, two to three guest speakers from academic departments and/or State offices are invited to give presentations on applications of remote sensing. Use is also made of audiovisual materials obtained from NASA and from the Applications Technology Center (University of New Mexico).

A major segment of the course is devoted to the characteristics of satellite imaging systems, particularly Landsat and Skylab. In order to provide students with a basis for judging the advantages and limitations of satellite image data, a comprehensive exercise is assigned to teams of 2 to 4 students from different disciplines. These exercises require a multidisciplinary approach to the preparation of land use maps (based on the U.S. Geological Survey classification system) of a selected area of Georgia from color infrared high-altitude aerial photographs, Landsat images and Landsat computer compatible tapes (CCT's). Comparisons of the accuracy and completeness of the maps are conducted and evaluations made of the relative merits of aerial photography, Landsat images and Landsat CCT's for land inventory purposes. In carrying out these projects students make use of equipment such as the I^2S viewer, Bausch and Lomb Zoom Transfer Scope, diazo printer, Richards light tables, and the Penn State ORSER program (for supervised and unsupervised classifications of Landsat digital data) which has been adapted to the University's IBM 370/158 computer system. Other remote sensing practicals are devoted to the analysis of radar (SLAR/SLR) and thermal infrared imagery of sections of Georgia.

Geographic Information Systems--GGY 824

The objective of this course is to gain perspective on the procedures of referencing, coding, storing and retrieving data required for land resource management tasks. Students are instructed in the techniques for digitizing maps and photographs. Particular emphasis is placed on remote sensor data in analog and digital formats for input to information systems. Efforts are made to acquaint students with commercial, State and Federal government information systems through literature reviews, field trips and invited speakers. A practical project is undertaken in which a data base is established and the CONGRID/IMGRID programs operational on the University of Georgia computer systems are used to evaluate/compare land suitability for a particular use.

Problems in Remote Sensing of Environment--GGY 825, 826, 827

These courses are restricted to graduate students and are designed to permit the student to conduct research on a remote sensing problem or to assess the applications of remote sensing techniques in connection with a thesis or dissertation topic. The scope of these courses is perhaps best illustrated by listing some of the subject areas which have been investigated:

1. Land-use and crop identification studies from Landsat data of Northeast China and the Sino-Soviet borderlands.
2. Geographic applications of Defense Meteorological Satellite Program data.
3. Potential applications of digital Landsat data for providing input to hydrologic models.
4. Development of a close-range photogrammetric system for the analysis of microscale landforms.

Several of these studies have resulted in papers presented at regional and national meetings. Grades are based on comprehensive student reports describing the objectives, procedures and results of the investigation.

Recent Advances in Remote Sensing--1 week short course

This short course is undertaken by the Department of Geography, University of Georgia and the Engineering Experiment Station, Georgia Institute of Technology, in cooperation with NASA's Earth Resources Laboratory, NSTL Station, Mississippi. The objective of the course is to provide an opportunity for state government employees and representatives from business and universities to become acquainted with the Landsat program. Emphasis is placed on recent trends in satellite remote sensing and on the utilization of digital image data in computer compatible tape formats. The opportunity for hands-on experience with the University of Georgia and Georgia Institute of Technology image processing systems is provided.

OVERVIEW

The remote sensing courses described in the preceding paragraphs have been well-received by students and appear to meet most of the objectives mentioned in the Introduction. For example, the applied nature of these courses has proven attractive to students facing limited job opportunities in traditional areas of employment. As a result, both enrollments and the number of terminal M.A. degree candidates requiring advisement and supervision have increased. Student interests are also much more diverse than in previous years due, in part, to concern over environmental problems related to pollution, energy, and ecology.

Table 1. Remote Sensing Courses Offered by the Department of Geography

Course No.	Course Title	Quarters Offered
GGY 420/620[1]	Use and Interpretation of Aerial Photographs	Fall, Winter, Summer
GGY 422/622	Advanced Photogrammetry	Winter
GGY 423/623	Remote Sensing of Environment	Spring
GGY 824[2]	Geographic Information Systems	Fall
GGY 825/826/827	Directed Problems in Remote Sensing of Environment	Fall, Winter, Spring in sequence

[1] 400/600 level courses are open to both undergraduate (junior/senior) and graduate students.

[2] Graduate students only.

Table 2. Remote Sensing Equipment Available in the Department of Geography for Instruction and Research

1. Photo Interpretation
   Mirror Stereoscopes
   Sketchmasters
   Saltzman Overhead Reflecting Projector
   Planimeters
   Tube Magnifiers
   Portable Light Tables
2. Photogrammetry
   Kelsh Plotter with H. Dell Foster Digital Recording
   Multiplex Plotter (for close range photogrammetry)
   Bausch & Lomb Zoom Transfer Scope
   Zeiss Stereopret
3. Remote Sensing
   I2S Mini Addcol Viewer 6040-PT
   Bausch & Lomb Zoom 70
   Bausch & Lomb SIS 95 Stereo Interpretation System
   Joyce Loebl MK III CS Microdensitometer
   Richards Light Tables
   Tektronix 4014 Graphics Terminal
   Altek Super Micro Digitizing System
   Arkwright Diazo Printer
   Perkin-Elmer Bantam CRT
4. Miscellaneous
   NUARC Copy Camera
   NUARC Platemaker
   Beseler Enlarger
   Tellurometer CA 1000
   Kern & Wild Surveying Instruments

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Session 5

A Perspective on Low-Cost Digital Image Processing

Highlights:

Session Chairman Edward Martinko introduced the topic and clarified terminology (see next page). The four papers in the session were then presented. Written versions appear on the following pages. Discussion was postponed until the four concurrent sessions which followed this plenary session.

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A PERSPECTIVE ON LOW-COST DIGITAL IMAGE PROCESSING

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INTRODUCTION

The use of remote sensing technology as a routine source of environmental and natural resources data has continued to expand at all levels of government and in private industry. This widespread acceptance of the technology has created a need for an increase in the availability and quality of undergraduate and graduate level remote sensing courses that train students in state-of-the-art remote sensing technology.

Hands-on experience and training in digital image processing is rapidly becoming an essential element of a strong remote sensing education. This training and experience is particularly important for students who intend to pursue remote sensing as a specialization. As these students develop their remote sensing education and career aspirations, their foundation in digital image processing will be extremely important in the face of rapidly changing computer and remote sensing technology.

As colleges and universities respond to this need through the design, implementation and upgrading of remote sensing courses, a number of key decisions must be made regarding and use and integration of digital image processing for instruction. Since few colleges and universities have unlimited funds for the acquisition of digital image processing capabilities, a realistic assessment of the costs, advantages and disadvantages of the available options must be made. The papers in this session attempt to outline the options through the shared experiences of those who have made such decisions.

TERMINOLOGY

The term "low-cost" is obviously relative with respect to specific objectives. For example, low-cost with respect to an individual course may be in the range of several hundred to several thousand dollars. With respect to a departmental, programmatic or university-wide digital processing capability for instruction and research, low-cost may range from ten to several hundred thousand dollars. Clearly, instructional, research and user objectives must be identified before decisions are made and costs evaluated.

Digital image processing on various computer-based systems is covered in this session. Geographic Information Systems (GIS) are also considered. The inclusion of GIS considerations reflects not only the need for training students in GIS technology, but also the impact of the computer-base on such technology with remote sensing data as a component.

Three main categories of computer systems are outlined:

1. University Main Frame System--This is usually a large system that supports multiple simultaneous users with large storage, memory capacity and processing power capabilities.

2. Microprocessor System--These systems are microprocessor-based with limited storage, memory capacity and processing power capabilities.

3. Minicomputer System--These systems usually offer large storage, memory capacity and processing power capabilities without the large number of simultaneous users typical of a main frame system.

The papers selected for presentation in this session attempt to address the advantages and disadvantages of these systems, hardware and software considerations, as well as associated costs.

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The 1981 Conference On Remote Sensing Education
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LOW-COST DIGITAL IMAGE PROCESSING ON A UNIVERSITY MAINFRAME COMPUTER

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INTRODUCTION

Until the mid-1970's, development of digital image processing systems took place in a limited number of research centers. These centers concentrated largely on research in digital processing techniques and in developing operational image analysis systems. While they also served a training function, this was not their primary role. Thus training in digital processing techniques was limited, and was conducted on systems that were not optimally configured for instruction. However, in the past few years, increased interest has developed in remote sensing in the academic world, and the active federal and state technology transfer programs have stimulated widespread interest within the public and private sectors. There is therefore a substantial and growing demand for scientists trained in digital image processing techniques. This widespread demand will necessitate an expansion of training programs into many centers across the country. One approach that holds promise to aid this expansion is the implementation of instructional digital image processing packages on university and college mainframe computers, to be accessed on-campus or from remote sites. Because of their availability and accessibility, academic university computers are well suited to this diversified training function.

This paper briefly summarizes the considerations involved in selecting and/or designing an instructional system for use on a university mainframe computer.

SOFTWARE CONSIDERATIONS

When designing software for instruction on a mainframe, or evaluating existing available packages, there are a number of considerations to be addressed when considering the suitability of the system planned. The following sections briefly outline the software and related hardware considerations:

AUDIENCE -- There are two general audiences: (1) undergraduate/graduate students in regular semester or quarter courses; (2) academics and the public and private sectors in short courses. The former audience will normally be taught on-campus while the latter may be on or off campus. University computers generally have a remote-access capability via telephone lines and can therefore support off-campus courses. A primary difference between the audiences will be in the length of the courses, and resulting depth of analysis. Students in regular courses will have more time available for experimentation and development of concepts, and may require a more flexible processing package, whereas in-service short courses are time-limited and require more tightly structured and directed work with fewer options, to emphasize general concepts. Because of time limitations, short courses and to a lesser extent student courses require shared-access to the computer, in order that a number of trainees can simultaneously run the programs. Most university computers are shared-access systems, unlike smaller systems which are often single-user. The level of sophistication of the training can vary widely for both audiences, from an introductory level up to advanced training of experience operators. The ability of a software system to handle this range will depend not only on its level of sophistication (to satisfy the advanced trainees), but also on the way it interacts with the user, i.e., how it presents and explains the processing options and results obtained (to guide the beginner).

CAPABILITIES -- While the basic concepts and approaches to digital image processing are similar in most systems, the actual methodology and procedures employed can vary widely from one system to another. Each system must therefore be evaluated separately as to the appropriateness of its procedures to an instructional setting. However, systems are developed around a specific set of capabilities. These capabilities can be compared:

Size of image/subimage -- Because of processing time and cost factors, instructional systems may restrict users to subimages of about 120x120 pixels in size. While university computers do have large disc storage capacities, the heavy demands placed on them by academic users normally result in restrictions on an individual user's available disc space. Thus a subimage size of 120x120 tends to be optimum for university mainframe computers. While this size is appropriate for most instruction, a capability to handle larger areas of a few hundred pixels square can be an advantage in advanced instruction and research. However, this may require the use of magnetic tapes or dedicated discs for data storage on university computers, which can restrict the flexibility and turn-around time of program runs. Such "off-line" approaches also deprive students of the interactive features that contribute to the instructional capabilities of a well-designed system.

Pre-processing and enhancement -- Desirable pre-processing functions include haze removal and destriping. Contrast-stretching is the basic form of enhancement, but histogram-normalization and band ratioing are desirable, as are edge-enhancement and smoothing. Textural operators are less common but are useful in instruction. None of these functions involve heavy computation loads and are easily handled by mainframe computers. Pre-processing data reduction through linear combinations using factor analysis is sometimes available, and is useful in illustrating information content and data redundancy. However, factor analysis programs often access library software routines, which may or may not be available on a particular university system.

Geometric correction and registration -- For analysis involving single images and small study areas, simple deskewing is often a sufficient form of geometric correction. However, if larger areas, multiple images or ancillary information such as digital terrain data are involved, then a geometric correction capability is necessary. Correction and registration techniques can be costly in terms of computer resources, but their implementation requires no special hardware or system capabilities, in most cases.

Classification strategy -- Supervised and unsupervised techniques form two distinctly different ways to define the land use/land cover categories to be classified. Both approaches have advantages and disadvantages, and both are commonly employed in operational systems. Neither approach is problematic on a mainframe.

Classification algorithm -- Once categories have been defined, there are a number of spectral pattern recognition algorithms employed to actually classify the image data. The parallelepiped and minimum-distance-to-mean classifiers are conceptually simple, easy to program and are rapid and cheap to run on the computer. Several commercial image processing systems using small computers use these classifiers. However, they are relatively inaccurate in comparison to the Bayesian maximum-likelihood classifier, which is more commonly used in operational systems. However, the use of this classifier is also considerably more expensive, and programs using it tend to be slow to run even on moderate-sized computers. It can cause lengthy delays in operation on shared-access systems.

Multitemporal Analysis -- While multitemporal analysis is conceptually the same as multiband analysis, and is therefore intrinsically feasible on most systems, registration of the data sets must be first performed, requiring a geometric correction capability.

Ancillary data and geographic information systems -- An increasingly important role of digital image processing is as a component of a digital geographic information system (GIS) in which multiple data sets are registered and transferred to a geo-based data storage, retrieval and analysis system. Thus Landsat data may be combined with ancillary data (e.g., elevation data) to classify land cover, and this data then combined with land ownership data for tax-assessment purposes. The main considerations in implementing a GIS on a university mainframe are related to the large data storage and handling requirements of even a small GIS designed for instruction, and the need for specialized peripherals (e.g., digitizers) to input the GIS data.

USER/SOFTWARE/HARDWARE INTERACTION -- The two modes of operation available on most university mainframe computers are batch and time-sharing modes. In batch mode, the user submits a complete set of data, programs and instructions to the computer, which performs the operations specified and outputs the results. Interaction between the program and user is not normally possible during operation of the program. Timesharing is a shared-access mode in which the user interacts with the program, responding to computer prompts with input of data or parameters to control the sequence of operations and computations carried out, and directing each stage of the analysis based on the results of previous stages. Programs written to operate in time-sharing mode would need to be modified to run in batch mode. As discussed earlier, most university systems support shared-access usage, with as many as one hundred or more separate users accessing the computer. This creates both advantages and problems for digital image processing instruction on a university mainframe. Multiple access allows many students to simultaneously run the image analysis programs. However, competing demands of other time-sharing users can slow operations considerably, and the more complex statistical classification programs can become unworkably slow at peak demand periods. In this case, a combination of time-sharing mode for most of the programs and batch mode for the slower classifier may be considered.

In an instructional setting it is important not to overwhelm the trainee with the minute details of file management and system operation, or to mystify him or her with unexplained short-form menus and instructions. However, it is equally important that the trainee is not so insulated from the workings of the system that it becomes merely a black box, or so deluged with lengthy explanations that, after the first run through the program, it becomes a time-wasting and tedious process. The user/system interface is, perhaps, a primary difference between systems designed for an operational setting, and systems designed specifically for instruction. The only way one can evaluate a particular system in this respect is by practical experience with it. However, a knowledge of the original intent of the system can indicate its applicability to instruction.

The use of university mainframe computers also introduces potential problems caused by the other demands on the system. During periods of peak load, particularly near the end of a semester or quarter, it may be impossible to access time-sharing during the day, and both time-sharing and batch operations can be extremely slow at all times. System maintenance down-time may occur at inopportune times, and system failure can occur in the middle of an extended program run.

COSTS -- Costs can be divided into those associated with acquisition and implementation, and those associated with operation of the system.

Acquisition costs can be further divided into hardware and software costs. The hardware costs generally relate to input and output (I/O) devices. Some systems use normal hard-copy terminal for I/O and involve no additional cost, whereas more sophisticated I/O may require a few tens of thousands of dollars for display devices with capabilities of delineating training areas on the display using joysticks, trackballs, etc. Output can be on hard-copy terminals, BW or color CRT displays, and electrostatic printer/plotters. One must weigh the costs of sophisticated I/O devices against the simplicity of the more common hard-copy devices.

Software costs involve either purchasing existing software, at costs of between $200 and many thousand dollars, or the programmer and computer costs involved in developing a new system, which will range from a few man-months' work to many man-years'.

Implementation costs relate to both hardware and software. Hardware costs will be incurred if specialized I/O devices have to be connected, and software costs will be related to the inevitable modifications that will be made to the software to implement it on the host computer. If the software is written in an unextended language, e.g., ANSI BASIC or ANSI-1966 FORTRAN, or in a moderately-extended common version, then software problems can be minimal. However, this depends on the software itself and the specific language available on the university computer. The potential cost of implementing software that does not conform to the host computer should not be under-estimated. System software requirements should also be considered, as software packages may require access to the statistical routines in IMSL, SPSS, SAS or BMDP, etc.

Operation costs can be subdivided into computer resources and hard resources. In student coursework, computer resource costs involve 'soft' allocations, and usage costs are not therefore generally a concern. However, computer resource costs for short courses will normally involve 'real' money, and the costs of running programs will be a major concern. In this case the exercises by the trainees will be more carefully controlled, and certain parts of the analyses may be pre-run to avoid duplication and unnecessary costs. Hard resources involve such items as telephone line rentals and usage charges, paper, terminal ribbons, film, etc. For on-campus courses, telephone line charges are minimal, but for off-campus courses they can be expensive. In this case a combination of time-sharing and batch mode can reduce telephone costs. If specialized peripherals are used, the cost of maintenance contracts and upgrading and replacement of the equipment will be a significant consideration.

SUMMARY

The use of university mainframe computers for instruction in digital image processing offers several advantages to the educator, but also has several limitations. Shared-access usage allows a number of trainees to simultaneously run the programs, but demands on the computer by other users can make access to time-sharing difficult and may slow down the programs. The university computer can handle large programs, but large data sets are often not accessible in time-sharing. The user does not have to bear the purchase cost or cost of maintaining and upgrading the computer, but has no control over computer operations, which can cause the system to be down at undesirable times. Computer operation costs can be nil for university courses, but the choice of instructional software package is largely determined by its compatibility with the host computer operating system.

Any consideration of an instructional image processing system must address both hardware and software characteristics and compatibilities. A well-conceived and implemented system can provide an invaluable educational tool, but incompatible hardware, software and audience will produce an educational disaster. Fortunately, the former is not difficult to achieve. Unfortunately, the latter is even easier.

EXAMPLES

Five papers will be presented in the panel session on 'Experiences in the Implementation of Image Processing for Instruction on a University Main Frame' following this session. They represent five different approaches and experiences and illustrate the variety of instructional systems developed. Eyton (1981) uses several sets of preprocessed image segments and a combination of FORTRAN programs and SAS setups operating in batch mode to teach an introductory course. Jensen (1981) developed IMAGES, an interactive system in BASIC specifically designed for undergraduate training in Geography. Rogers (1981) describes an interactive system which uses desktop Remote Analysis Stations to communicate with a central computing facility via telephone lines. Turner (1981) discusses ORSER, a comprehensive package of computer programs developed since 1970 for advanced remote sensing instruction and research. Williams et al (1981) developed a FORTRAN-based interactive system for use in advanced undergraduate and graduate training and in short courses for in-service training.

These five papers are only a sample of current instructional image processing, and an even smaller sample of operational systems. Listings and details of other systems can be found in Danielson and Ford (1977), Cosmic (undated), EROS Data Center (1978) and Carter (1977).

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MICROPROCESSOR BASED IMAGE ANALYSIS SYSTEMS

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ABSTRACT

The EROS Data Center has undertaken a project to define the specifications of a microprocessor based remote image processing station, designed both to extend the use of Landsat and other remotely sensed data to field offices and to provide a low cost device to assist in the teaching of digital image analysis techniques. It is not intended to compete with large computer-based or mini-computer-based interactive systems, but will complement them through remote access to their resources.

In the traditional realm of digital analysis, three major approaches have been employed. These are batch processing, interactive text processing and console oriented interactive video processing.

In a batch processing mode a series of job steps are issued prior to a run by the system user. The job is executed at a later time and is totally out of the user's control during execution. In the event of a problem with the data or an invalid instruction, the job will either terminate prematurely or pursue some default processing scheme until the task is completed. The user will not know the outcome of his run for hours or days later until he picks up his output. This output will generally be in the form of tables and summary statistics rather than in an interpretable image format.

In interactive text processing runs, the user, usually at a remote terminal, has control of each step of a processing run and is usually able to detect and correct problems in a timely manner, reducing the probability of a wasted processing run. As in a batch run, the user is unable to view his data in an imagery display format and must depend instead on summary statistics and numerical data to indicate the probable state of his imagery.

In a console oriented interactive video processing system the user is able to directly view and analyze his imagery after each processing step has been completed. The utility afforded the user by this approach allows rapid analysis of his data in a minimum real time interval.

The drawbacks of processing image data on the above systems are organized into two related groupings. Firstly, computers capable of performing this type of processing function are expensive and it is costly to acquire multiple display consoles for these systems. Thus, these facilities are limited in number. This limitation is increased by the normal operating mode of these systems in which the analyst spends long periods examining the imagery displayed on the system console. The second problem is the difficulty of traveling to and scheduling time on such a system in competition with other users in a timely and cost effective manner.

The remote image processing station is conceptually a low cost, on site, multifunction alternative to the above modes made possible by the technological advances of the past ten years.

This project is a phased development task which includes prototype hardware design, user definition, development of data compression techniques and data transmission protocols, remote unit software design, host unit software design, system testing, field evaluation, and solicitation of industry involvement.

The remote image processing station (RIPS) will have numerous processing functions for image analysis and geographic information systems and will be able to interface with many host computers. Thus, RIPS will be able to input and analyze several sources of geographically referenced image data such as meteorological, Landsat, topographic, as well as polygonal cartographic data structures. These functions will lend themselves to an educational environment as well, making this device useful as a tool in teaching digital image processing techniques.

NASA

CORSE-81

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DIGITAL IMAGE PROCESSING ON A SMALL COMPUTER SYSTEM

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1. Introduction

There are a number of different computer tasks involved in image processing for remote sensing applications (c.f., [1]). These tasks vary widely in the way they exercise the various components of a computer system. Some, such as classification and clustering, are limited by the raw calculating speed of the central processing unit (CPU) and are referred to as CPU-bound. Others, such as reformatting of data tapes, are limited by how rapidly data may be read into and written from the computer system, and are described as Input/Output (or I/O)-bound. Still others, for example, selection of tie points for image registration, are primarily related to human/machine interaction, and are classified as interactive.

The suitability of a computer system for various image analysis activities depends on the characteristics of the CPU and attached peripheral devices. Particular tasks may be performed better on some systems than others. The rest of this paper discusses the advantages and disadvantages, and selection, of minicomputer systems for image processing.

For the purposes of this discussion, a "minicomputer" is considered to be any computer with a system cost in the range of $30K - $100K. Such systems are currently characterized by:

- a short word size, typically 16 bits (although 32 bit machines are becoming more common);
- a limited maximum memory size, typically 128K to 256K words (although newer machines may allow up to 2M words);
- limited CPU speed, particularly for calculations involving real numbers; and
- relatively slow transmission speeds between the CPU and peripheral devices.

2. Minicomputer Advantages

One of the major advantages of a minicomputer-based image analysis system is the low initial cost relative to mainframe systems. This is coupled with a relatively low operating budget for items such as maintenance, operational staff, and controlled environment.

Another advantage is local control: a small system completely controlled by a department teaching remote sensing may be allocated as necessary, and on relatively short notice. This guarantees maximum availability, so educational use will not be restricted by pricing or scheduling policies of a central computer center.

A third advantage is the wide variety of relevant peripheral devices (image displays, digitizers, plotters) with high-speed interfaces to the more popular minicomputers.

3. Minicomputer Disadvantages

The primary disadvantage of a minicomputer-based system is speed, or rather, lack of speed. Use of CPU-bound or I/O-bound functions is more difficult on a minicomputer. For example, it has been estimated [2] that it would take 90 hours of CPU time on a relatively large minicomputer to classify a full Landsat scene into 30 classes. The same operation on a typical mainframe system would take perhaps two hours. Thus practicality and system reliability limit a minicomputer-based system to processing a low volume of relatively small images (less than 512 x 512, say). This is not a particular problem for classroom use, but is a distinct disadvantage for graduate education and research activities.

The most straightforward approach to providing the processing power needed for analysis of large images is to make use of a large mainframe processor for those CPU- and I/O-bound tasks which cannot realistically be done on a small system. This approach requires no capital outlay, but does require additional funds for purchasing the outside processing time.

A second disadvantage is the limit on program size and size of main memory for many popular minis. This reduces the amount of image data a task may operate on at any one time, increasing the I/O traffic in tasks which may already be I/O-bound.

4. Implementing a System

Several manufacturers make turnkey systems based on minicomputers (consisting of computer, display device, and software) for prices ranging upward from about $150K. This is a possible approach to developing an image analysis computer capability, but represents a significant initial investment.

A more realistic possibility is that a department interested in teaching image processing as related to remote sensing will select (either for initial procurement or from among systems already available) a hardware system, and separately acquire software.

4.1. Software Selection

Software development is an expensive and time consuming process, and end users are advised to avoid it if at all possible. In fact, for most end users, the availability (or lack) of software for particular combinations of computer hardware AND operating system may be the determining factor in hardware selection.

It is preferable to acquire a complete software package, rather than trying to integrate separate programs for each function. One inexpensive source for image processing software is COSMIC [3], with prices for a typical package in the $2K range. Recent research in transportable image analysis software [4] provides hope that this software integration problem may be simplified in the future.

It should be noted that many packages do not provide all the functions needed for remote sensing applications. This is true particularly for data tabulation functions, display oriented activities, and software for geographic information systems. However, several display manufacturers can provide complete image analysis software systems which make use of their display's capabilities.

4.2. Hardware Selection

A minimal hardware configuration for image analysis activity consists of the processor and memory, disk storage, tape drive for loading images, console terminal (doubling as printer), and a line-oriented CRT terminal as an analyst's station. A typical cost for the basic configuration is $41K, with monthly maintenance charges of $315.

To accommodate increased numbers of users or more demanding image analysis tasks, the hardware system should be expandable. In fact, the possible expansion paths should be investigated <u>before</u> the system is purchased. Such expansion can be implemented in phases, based on increasing demand, to reduce the impact of additional expenditures [5]. Areas to be considered (and prices associated with each component) include:

- Increase of processor speed. A floating point processor ($3K) yields more rapid results for real arithmetic calculations. A cache memory ($4K) speeds execution of all non-I/O instructions.

- Addition of memory. A larger central memory ($4K/128K words) allows more simultaneous users on the system without degrading response time. Additional disk storage space ($12K - $22K/40M words) allows more images to be stored on-line, with correspondingly faster access time.

- Addition of special purpose peripheral devices. Probably the most useful such device for analysis work is a raster scan graphics display terminal. At a minimum, such a terminal allows easy examination of images. More expensive displays provide fast hardware implementation of common image processing functions ($5K - $80K, depending on capability).

Another class of useful peripherals includes inexpensive devices for production of hardcopy images. Candidate devices include: line printers ($5K); dot matrix printer/plotters ($10K), which can produce greyscale prints which may substitute for film output or display use for some image analysis functions; and a video signal camera ($14K) which records directly on film from the RGB signal produced for a display monitor.

Finally, a digitizer ($7K - $15K) allows input of region boundaries for data aggregation or graphics overlays for a display device.

A rather substantial image analysis facility, consisting of the basic computer configuration, cache memory and floating point processor, printer/plotter, $25K color display terminal, and a video signal camera, would cost about $97K, still within the (arbitrary) price boundaries of a "small" system. Such a facility, however, could be slowly built up from a much more modest initial system.

5. Summary

A minicomputer-based image processing facility provides a relatively low-cost entry point for education about image analysis applications in remote sensing. For low volumes of small images, a minicomputer has sufficient processing power to produce results quite rapidly. It does not have sufficient power to perform CPU- or I/O-bound tasks on large images. Operations which are most cost effectively performed on large mainframe computer.

A minicomputer system equipped with a display terminal is ideally suited for interactive tasks, which occupy most of a human analyst's time in image processing.

Software procurement is a limiting factor for most end users, and software availability may well be the overriding consideration in selecting a particular hardware configuration. The hardware chosen should be selected to be compatible with the software and with concern for future expansion, to support increases in the number of users and number of images processed as image analysis becomes integrated into the remote sensing curriculum.

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"Considerations in Developing Geographic Information Systems Based on Low-Cost Digital Image Processing"

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Introduction

Interest in Geographic Information Systems has risen with the necessity of handling large volumes of spatially related data extracted from numerous diverse sources and data bases. GIS of varying complexities and sizes are being developed by business, industry, and all levels of government from local to state and federal levels.

Commensurate with this activity is a recognition that students seeking careers in these areas should receive exposure and training in the design and creation of GIS. In some cases such instruction may be as a formal course devoted entirely to the subject. More often it is found as a component of cartography, remote sensing, and in some instances planning courses.

Of consideration here is the role of low-cost digital image processing in developing GIS. A GIS is normally a data oriented decision support system designed to catalog, store, process, and analyze spatial data. Such a computer based information system contains spatial data in machine readable format; this digital information is used to search, measure, and compare these data in an attempt to allow for analysis of geographic information beyond the scope of the original sources. In respect to this objective, it is desirable that geographic information systems should provide the following functions:

1) Data Capture -- The ability to place the data of interest into the system;

2) Data Management -- The ability to store, structure and handle data in an efficient manner;

3) Data Manipulation -- The ability to retrieve and analyze the desired data elements and items; and,

4) Data Display -- The ability to present the results of analysis, search, and comparison in a useful format.

The capabilities of a GIS are a function of the system's major data orientation, the hardware powering the system, and the software driving the system, although the latter is functionally constrained by data and hardware considerations.

While many bits and types of data can be used as input into a GIS remote sensing is perhaps one technique increasingly being employed not only as a data base but also for analyzing temporal and spatial changes for the area covered by the system. Black-and-white aerial photographs, color, and color-infrared photography are standard remote sensing items used in such operations--particularly in GIS designed for small areas (e.g. small municipalities, city and county government). Although such data may be digitized upon occasion it is generally analyzed optically by human interpreters and subsequently encoded at its proper space in a GIS.

However, digitally processed data in the form of Landsat multi-spectral scanner computer compatible tapes have been and are continually being examined and employed by numerous users as an integral component of GIS. This is particularly true for systems covering areally extensive areas and for those users with large computer systems at their disposal.

While much attention has been paid to the implementation of large main-frame computers for GIS use and are addressed in other session papers little work has been done in exploring the role of low-cost digital image processing systems. In the following paragraphs some of the problems, considerations, and potential of digital image processing systems costing $20,000 or less are reviewed.

Considerations

Data Handling: GIS are intended to handle large quantities of data from diverse formats, register all input to a common mapping or recording base, and display or output any or all combinations of these factors for decision makers. Such data may be areal (e.g. land use maps, soil maps, political boundaries), point data (e.g. historical sites, school and public service locations), statistical data (e.g. census tract data), non-point data (e.g. micro-climatic conditions such as wind flows, or hydrologic factors), and/or linear data (e.g. transportation elements or geologic lineaments). The potential volume of such data can overwhelm a small micro-processing system and care must be taken as to what and how much can be stored and retrieved efficiently. Since such DIP systems may be required to stand alone data handling is not an insignificant problem -- and one that cannot be avoided by tying a small system to a large main-frame unit.

From an instructional point of view the classroom environs poses related time/cost considerations. First and foremost the instructor must be familiar with both GIS and LCDIP operations. In designing a course or part of a course devoted to this subject the instructor must: (1) consider the audience (undergraduate or graduate, workshop or short course for agency personnel); (2) devise a training base or study area of appropriate size; (3) collect remote sensing, cartographic, and other data input of the types listed above; (4) design exercises and types of problems capable of being completed by students with regard to class size and DIP limitations; (5) digitize input or devise efficient procedures for the class to do so; (6) decide the level of instruction appropriate given the background of the intended class and their use of it in their careers/employment. Data configuration (e.g. types of remote sensing imagery) cannot be overlooked. Finally, the size of the class must be defined in light of the amount and type of hardware to be used.

Hardware: There are very few DIP systems on the market today that can be purchased for less than $20,000. Although a few enterprising individuals have designed customized systems from bits and pieces extant at their universities very few people have the skills or resources available to create such a "one-of-a-kind" system. Three commercial systems are available: IMPAC (Image Analysis Package for Microcomputers) by Egbert Scientific Software; ERDAS by Earth Resources Data Analysis System; and APPLEPIPS (Apple Personal Image Processing System). The latter is not a commercial system as such but an Apple II computer with mini-floppy disk drive and color television combined with software programs developed at NASA Goddard Space Flight Center. While each system can handle remote sensing input (especially Landsat CCT's) the further step of adapting such hardware for GIS work requires that storage for non remote-sensing input be provided as well as output procedures. Additionally, the advisability of digitizers, plotters, and graphics boards suitable for presenting data planimetrically must be considered. In essence, software components must be available and viewed in light of hardware limitations.

Software: Most work in this area has been done in regard to the handling and manipulation of remote sensing input data. However, even here there is the necessity of having access to a main frame computer. A Landsat CCT is too large to be handled by a microcomputer. Therefore the CCT must be subsetted and transferred electronically to the microcomputer floppy disk for storage and use by a LCDIP system. This implies that the instructor has some programming knowledge or that a liaison with the computer center staff be established in order that an interface can be established between the computers. Once this is accomplished various routines can be created by the operator or "canned" programs run on the data. Examples of the latter remote sensing programs include: density slicing, supervised or unsupervised training and classification, and generation of line printer maps. Obviously, the speed and sophistication of the algorithms/processing is less than that capable of a main frame computer -- nor can as large an area be analyzed at one time. The advantage lies in training students in the techniques universal to digital image processing - with specific input to GIS.

It is in the GIS software considerations that perhaps the most challenging aspect of LCDIP exists. A fundamental decision is whether the system will be an image based GIS existing in a raster format or whether it will combine digital image data with other data sources in a polygonal, topologically structured format. Clearly, the former case is the less demanding situation in respect to computational resources, but it is also a relatively inflexible information structure. In both cases, however, a number of software considerations must be addressed. It should be noted that the user must match the potential desirability and effectiveness of analytical, comparative, and output-display capacities with the amount of computational resource initially available and also with respect to possible system upgrades. The basic software system, however, should include programs for:

1. Data entry - conversion - digitization

2. Geo-referencing - geometric correction

3. Data structuring

4. Editing - updating (image, attribute and textual data)

   a) delete-add
   b) replace-change

5. Analyses and retrieval

   a) search
   b) measure
   c) compare
   d) overlay
   e) aggregate-disaggregate
   f) window

6. Output drivers

   a) soft copy
   b) hard copy

7. Data management

   a) file structuring

These various softwares provide the substance of the GIS. Low cost processing, the goal of microcomputing, can produce systems relatively limited in GIS capabilities. As a consequence, it is imperative to benchmark these systems in respect to the type of information processing that is your ultimate goal.

Costs: Costs should be considered as tangible and intangible factors. The latter refers to the costs of time on the part of the creator/instructor/user of a LCDIP system for GIS. As can be seen from the above considerations there must be a commitment in time on the part of several parties. The system must be purchased, brought up to operational status, and then procedures and exercises for instruction created. A data base must be created from a number of sources including remote sensing imagery, cartographic products, and statistical data. Last, but primary in the entire concept is the purchase of existing hardware and software equipment. Harware systems can run from $2500 for an Apple computer alone with all else being generated by institutional "soft" monies and the instructor's time to $20,000 for a DIP system that includes hardware and software programs. At both ends of the spectrum the added but imprecise cost of GIS cartographic factors must be added as must the cost of Landsat CCT's or other digitial image data.

Future Prospects

Today's technology is capable of supporting a limited GIS on a microcomputer, but just barely. While LCDIP is an actuality the bottleneck lies in the interface. LCDIP is designed to handle small quantities of data economically. Not every application requires a large computer-core-memory and the examination of extensive areas, nor can every potential user afford one. On the other hand a GIS by definition is required to handle, store, and update large quantities of data input/output from multifarious sources and present it in a single uniform format (i.e. coordinate system). Thus, the two components are at opposite ends of the data analysis spectrum. While such dichotomy may severely limit their operational combined use it is believed that the two can be merged for instructional purposes and for limited GIS applications where the volume and complexity of input is restricted. The major concern at present lies in the design and storage of a coordinate system and the subsequent rectification to this base. How successful this will be is largely a function of the accuracy and data requirements of the user.

Session 5-a

Low-Cost Digital Image Processing on a University Main Frame

Session Highlights:

Under the chairmanship of T.H. Lee Williams, University of Kansas, this session included four papers, all of which are printed on the following pages. The session chairman summarized the session as follows:

The four contributors and chairman each gave a ten-to-fifteen minute presentation in which they summarized the approach, capabilities, costs, experiences, advantages and disadvantages of their respective systems. The session was then opened to a group discussion between the audience and panel. The audience was particularly interested in the costs, compatibilities and availabilities of the systems. The panel presentations were successful in presenting and comparing the various approaches to using a university main-frame, and discussion focused on specific details of the various systems rather than on a wide comparison of overall approaches.

Session reporter was Tom Hennig, Purdue University.

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INSTRUCTIONAL IMAGE PROCESSING ON A UNIVERSITY MAINFRAME -- THE KANSAS SYSTEM

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INTRODUCTION

The Kansas Applied Remote Sensing (KARS) Program and Department of Geography-Meteorology have developed an interactive digital image processing program package that runs on the University of Kansas central computer, a Honeywell Level 66 multi-processor system. The module form of the package has allowed easy and rapid upgrades and extensions of the system since its initial development in 1979. It has been used in remote sensing courses in the Department of Geography, in regional five-day short courses for academics and professionals, and is also being used in remote sensing projects and research.

AUDIENCE/PURPOSE

The package was developed primarily for use in two instructional settings: (1) a semester-long graduate-level course in quantitative remote sensing offered through the Department of Geography; (2) a series of NASA-funded five-day short courses offered by the KARS Program for federal, state and local agency personnel and for academics and private industry. The courses currently are taught on-campus but can be offered off-campus using line-printer terminals and phone links to the university computer. The system has been accessed from other states for demonstration purposes. Although its initial role was primarily instructional, experience in using the system indicated its potential for operational digital image processing projects. Subsequently, it has been used extensively in KARS and Geography applications and research projects. Its modular, subroutine-oriented structure, relatively simple FORTRAN programming and interactive time-sharing mode make it an ideal vehicle for image-processing research for both faculty and graduate students.

CAPABILITIES AND OPERATION

The package comprises three self-contained modules of processing functions: subimage extraction and rectification; image enhancement, preprocessing and data reduction; and classification. A description of its use in a typical course setting is described below:

Subimage extraction -- A complete Landsat scene is set up, prior to the course, as random-access computer disc files. The students work in pairs and select their own 120x120-pixel study areas and use a grid coordinate overlay on the Landsat image to determine the row and column coordinates of their selected area. They give these coordinates to SUBIMAGE, which extracts the proper lines, unpacks and deskews them, and writes the data for each band to a separate file. SUBIMAGE is the only batch program in the package. Batch mode was required because the image is stored on a removable disc pack that must be specially mounted at the University Computer Center and normally cannot be accessed in time-sharing. The subimage extraction routines are system-specific to the University Honeywell, and modified programs would have to be developed for other computers.

Programs for haze removal, destriping and geometric correction are being developed.

Enhancement and Preprocessing -- Program HISTGRSH produces raw image histograms and generates, on a hard-copy terminal, enhanced grey-shade images having between three and ten grey levels. Simple linear contrast-stretching, histogram normalization and direct specification of histogram intervals (1) are available as enhancement options. The images are output on a DecWriter IV line-printer terminal or equivalent that has variable character and line-spacing. By using 16.5 characters per inch (cpi) and 12 lines per inch (lpi), X-format Landsat scenes can be displayed with a linear distortion of less than 1½%. EDIPS format images, which are resampled to a 57x57 m square pixel, require settings of 12 cpi and 12 lpi.

The students can also apply a variety of other enhancement and data-reduction operations to their images. SMOOTH uses a 3x3 moving window average to generate a smoothed image. EDGE employs a 3x3 moving window and doubles the deviation of a pixel from its local neighborhood mean (2) to generate edge-enhanced images. TEXTURE employs a 3x3 moving window and computes the absolute deviation of a pixel from its local neighborhood mean. RATIO computes and rescales the ratio of two bands. TVI computes a modified form of the Transformed Vegetation Index (TVI), for use in vegetation studies (3). The modified images can be saved and used later in the classification routines, if desired.

Programs to perform data reduction using SPSS factor-analysis routines (in batch mode) are also available.

Classification -- The grey shade images that students produce are used to locate and select ground truth sites for a supervised classification of the study areas. Students first develop a role model and specific project for their area (e.g., they are wildlife management specialists and wish to map wildlife habitat), and define the land cover/land use categories they wish to map. They then select training sites for each category and refine their training sample data using PIXVAL and SCATPLOT to print out the digital number values and generate scatter plots of their training samples. The students are then prepared to run SCLAS, a maximum-likelihood supervised classifier. A schematic diagram of SCLAS is given in Figure 1. They input their training site data (STRSAM), and then determine the statistical separability of their categories using SEPRA, which uses a modified version of the transformed divergence statistic (4). Training sample data can be displayed by SCATPLOT, and categories then combined (SCONDENS) or the maximum-likelihood classifier (MAXLIKE) run and a classified map produced. ACUCHECK uses the training sample data to assess the accuracy of the classifier and produces a classification accuracy contingency table. The students then have the option of producing partial maps of selected categories (PARTMAP), or binary maps ("flaps") of individual or groups of categories (FLAP) that are used to generate a final color map using diazo transparencies. When a student signs off, his classified image and category training data are written to file. On subsequent runs, the image and data are read from file and the student can continue from where he left off. The final option available in producing classified maps is individual selection of category symbols. This is used to cartographically combine (CARCOM) categories that are spectrally distinct but may be informationally similar (e.g. bare soils with different moisture levels) with regard to a specific application.

After the students have completed the supervised classification, they are introduced to unsupervised cluster analysis and classification, and subsequently run UCLAS. A schematic diagram of UCLAS is given in Figure 2. CLUSTER uses a sample of pixels from the image and a sum-of-squared-errors clustering routine (4) to generate up to 20 clusters. The student specifies the number of clusters and has the option to seed cluster center point values into the program. Cluster category statistics and a scatter plot of cluster means are produced. A statistical category separability analysis is produced using SEPRA. Usually, a maximum-likelihood classification is then produced using MAXLIKE, and again partial maps or flaps of categories can be obtained. The classified map is then compared with ground truth (e.g., aerial photography and/or field data) to identify the cover type of each category. Based on the ground truth and separability analysis, category combinations are planned using either statistical combination (the categories are merged and a new cluster analysis (UCONDENS) and classifier run) or cartographic combination (the categories are kept separate in the classifier and combined cartographically (CARCOM) by using the same symbols in the final map).

Both SCLAS and UCLAS are totally interactive and allow great flexibility and choice by the student in the sequence of operations run. Exercises to date have used single-date four-band Landsat data, but the system has the capability of multidate analysis and the use of ancillary data (e.g., digital elevation data) in the classifier, provided the data can be registered properly. Feature selection options are being developed to reduce the dimensionality of the data. The system will also, over the next two years, be integrated into a Landsat-based geographic information data base and analysis package.

AVAILABILITY AND COSTS

Source code for the software, documentation and sample runs will be made available to other potential users, but distribution details have not yet been finalized. The package is designed to run interactively and produce properly-scaled map output on a hard-copy terminal with appropriate characters and line spacing. The DecWriter IV (LA34) terminal sold by the Digital Equipment Corp. for about $1200 has been the most commonly-used for this package at the University of Kansas. Other terminals with proper scaling will work, also.

The programs are written in Honeywell Level 66 time-sharing FORTRAN, formerly known as FORTRAN-Y, running under the operating system GCOS. This is an extended ANSI-1966 version similar to WATFOR and other common extensions. The program code differs from standard in its use of free-form statement positioning, upper and lower case, variable names of up to eight characters and character data strings delimited by " or '. The programs use both sequential and random-access disc input and output. Random I/O supports user-specified record lengths. Terminal I/O requires 132-column lines. The KU Honeywell computer does not support byte-oriented (LOGICAL*1) or INTEGER*2 memory allocation. An implementation allowing these would be somewhat more efficient.

Computer resource costs will vary according to the size of the class. A semester-long course in the Geography Department with 13 students used $1000 in computer resources. However, this cost came under the soft money heading for instruction, and involved no out-of-pocket expenses. In the five-day short courses offered by KARS the supervised classifier is omitted, all the trainees work on the same study area, the initial cluster analyses are pre-run for the course, and less time is available for rerunning and refining the classifier. In this case, computer costs for 15 students working in five groups of three amounted to $350. The only noticeable hard resource costs other than computer time are telephone line rentals and terminal ribbons, which cost $20 for one semester (three ribbons).

EASE OF ACQUISITION/IMPLEMENTATION/OPERATION

As mentioned, the package has no specialized hardware or system software requirements and is transportable and easily implemented. The routines to generate subimages will, however, have to be developed for each location, although sample image sets are available. Operation of the system in an instructional setting is straightforward as all the programs are interactive and conduct a conversational dialogue with the user. No problems have been encountered through student misunderstanding of questions or prompts. No prior experience with computers is necessary to run the programs.

EXPERIENCES

The software package was developed to be used in either a semester-long or five-day short course. It allows either detailed or more cursory analyses while maintaining a logical sequence of operations. Experience has shown that encouraging students to develop a role model and project and to select their own study areas greatly enhances their interest and commitment to the work. Processing routines were developed to be as close as possible to 'operational' systems in terms of algorithms used, while maintaining an emphasis in understanding the concepts behind the operations.

The system has, to date, been used in two five-day courses and one semester-long graduate course. The primary problems in using the system have arisen from the slow turn-around time and difficulty of signing onto time-sharing when the university computer is busy, particularly near the end of the semester. Students in the semester course normally worked on the computer in early mornings, late at night, or over weekends. Even then, the classifiers SCLAS and UCLAS were often slow to run because of their size and the complexity and number of computations involved. However, this slow turnaround is still faster and more interactive than batch operations, and the students did not experience undue frustration.

As noted above, the package is being continually upgraded. Because of its modular form and simple FORTRAN programming, it is relatively easy to modify. Since it fosters experimentation with ideas in digital processing, it has been an important catalyst for faculty and graduate student research.

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FIGURES

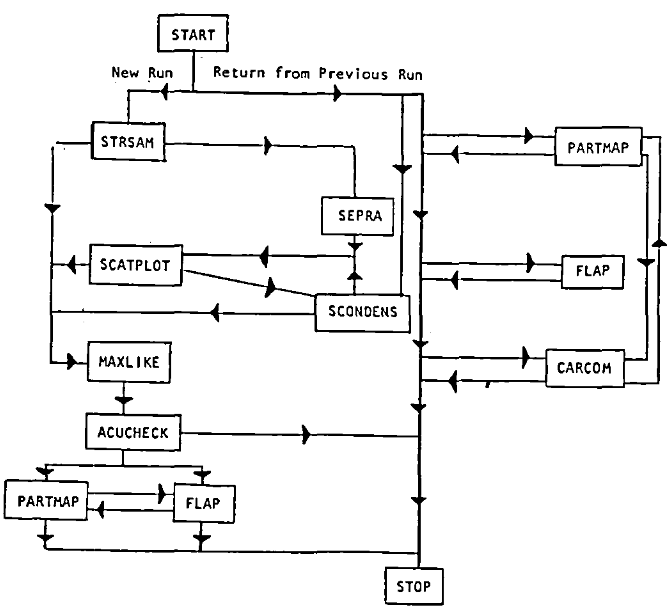

Figure 1. General schematic diagram of SCLAS, the supervised classifier.

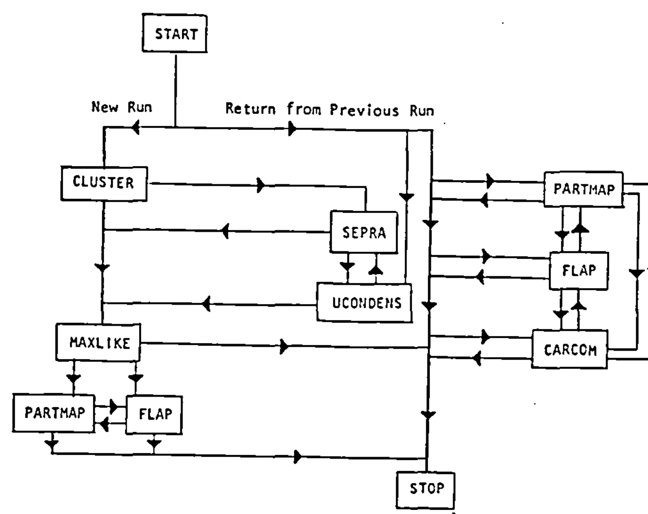

Figure 2. General schematic diagram of UCLAS, the unsupervised classifier.

CORSE-81

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IMAGES--An Interactive Image Processing System

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INTRODUCTION

Geography departments provide 38 percent of the remote sensing education in the United States [1]. Most geographers teaching remote sensing would like students to master both visual photo-interpretation and interactive digital image processing analysis methods [2]. Such analysis provides insight into environmental and sensor parameters which interact to create the image. It also provides practical experience in digital image processing which has become an important aspect of remote sensing research and application [3]. The IMAGES interactive image processing system was created specifically for undergraduate remote sensing education in geography. The system is interactive, relatively inexpensive to operate, almost hardware independent, and responsive to numerous users at one time in a time-sharing mode. Most important, it provides a medium whereby theoretical remote sensing principles discussed in lecture may be reinforced in laboratory as students perform computer-assisted image processing. In addition to its use in academic and short course environments [4] the system has also been used extensively to conduct basic image processing research.

APPROACH TO THE IMAGE PROCESSING SYSTEM

Many image interpretation procedures used in remote sensing can be reduced to a finite number of explicit operations; consequently, they may be automated. Potential procedures were scrutenized in light of the following questions prior to being made a component of the image processing system: What remote sensing concepts do students encounter in lecture which are difficult to master? Will computer-assisted image processing improve the understanding of these concepts?

The goal of bringing students to a higher level of conceptual and practical understanding of remote sensing is accomplished using structured assignments and the IMAGES digital image processing system. Students with no previous experience in digital image processing begin by previewing a catalog of image processing programs and selected images. Users then select a program from the catalog and initiate an interactive session. The conversational nature of the BASIC language allows "framed" instruction consisting of three parts; a stimulus, a response, and an occasional reinforcement [5]. For example:

STIMULUS: Which IMAGE would you like to use?
USER RESPONSE: 4
REINFORCEMENT: IMAGE4 copied (or IMAGE4 is not available for analysis)

Each program has internal error-checking to query the user if inappropriate data are entered, however, this does not preclude all student logic errors.

Using criteria established by geography's modest heritage of computer-assisted instruction [6], the computer-assisted image processing system may also be classified as being of the "branching" type. Branching programs are those in which the software analyzes student response to determine which of several alternatives to present next. Students enter statements, variables, or equations to generate outcomes which are seldom, if ever, identical. Students demonstrate their comprehension of principles by generating thoughtful, creative outcomes. They are then challenged to interpret and explain the significance of their results.

SYSTEM CAPABILITIES

The flow of information through the image processing system will now be discussed. One program, BANDSEQ, is used only by the instructor to place Landsat digital data onto disk. All other programs are accessible to the student. Also, note in the following review of programs that if a plotter is available optional fortran programs are provided which produce improved map output. The default is visual analysis at a CRT or examination of line-printer output.

DATA ACQUISITION AND DISPLAY

BANDSEQ. This program reads Landsat band-sequential (BSQ) data for EROS tapes produced after February, 1979. It is approximately 70 lines of assembler code which places four BSQ files out on a disk. These files are named IMAGE1, IMAGE2, IMAGE3, and IMAGE4 and correspond to Landsat bands 4, 5, 6, and 7. These IMAGES may be as large as 300 x 300 and are made accessible to students for interactive analysis.

SUBIMG. Students obtain SUBIMAGEs from the IMAGES residing on disk. The maximum subimage size a student may create is 110 x 110 pixels, a convenient dimension for line printer output. STATistics and HISTOgrams are performed on SUBIMG data prior to making a GREY map.

GREY. A GREY map of a SUBIMAGE file is produced by specifying the number of levels (up to 32), class intervals, and symbolization.

BRIGHT. A BRIGHTness subimage is produced by integrating the digital number (DN) values for all four Landsat SUBIMAGEs [7]. After processing in GREY, it is useful for supervised training site selection.

PLOT [optional]. Students may instruct GREY to create a matrix which is used in PLOT to produce improved grey scale maps on a Calcomp or Versetec plotter.

Preprocessing

FILTER. Using two-dimensional convolution filtering, high or low frequencies in the spectral data are computed and stored as new SUBIMAGEs [8]. These may then be used in other image processing procedures.

TEXTURE. First- and second-order texture SUBIMAGEs may be computed [9].

EDGE. This program performs difference or Laplacian edge-enhancement [10].

CHANGE. Differencing logic is used to produce a change SUBIMAGE if registered, multiple-date images are available. When histogrammed, pixels which exhibit significant change in DN value between dates generally lie in the tails of the distribution. The change image can then be mapped using GREY to identify areas of change between two scenes [11].

Data Analysis

TRAIN. Training sites anywhere in the entire IMAGE (not just within SUBIMAGEs) are identified. STATistics and HISTOgrams are run on the TRAINing sites.

TEST. Test sites are identified to assess classification accuracy. The program operates exactly like TRAIN, except it is not permissable to obtain STATistics or HISTOgram a TEST file.

STATS. The mean, standard deviation, minimum and maximum pixel values, and the total number of pixels for any SUBIMAGE or TRAINing file are obtained. Pixel values are stored in SORTed files for access by HISTO.

HISTO. A HISTOgram is displayed of any file run through STATS. The user defines the range of the HISTOgram, number of columns, character value, and symbolization.

SPECTRL. Co-spectral plots based on mean and standard deviation statistics for each class and each band are displayed in bargraph format [12]. The user may selectively include certain classes and/or channels to determine which features to use in the CLASSification.

PIPED [optional]. If a plotter is available, the user may instruct PIPED to plot each training class parallelepiped (mean $\pm$ n standard deviations) in two or three dimensions [13].

Supervised Classification

THEME. Traditional parallelepiped classification using Boolean logic is performed [14]. The user specifies the SUBIMAGEs, to be used and the lower and upper range of the multidimensional thresholding. Individual thematic maps are created for each class, along with training and test performance.

LAYER. This program is exactly the same as THEME, except that layered classification logic is applied to classify the scene [15].

DCLASS. A minimum Euclidian distance discriminant analysis is performed [16]. The user specifies the classes, channels, and symbolization to be used. All classes are displayed on a single thematic map and each pixel is assigned to only one category. If a plotter is available, the user may route a classification matrix to PLOT for improved thematic map output.

Utility

STATUS. This file contains information on all other files and must be ATTACHed by each program.

FILES. This program scans the contents of STATUS and allows the user to review and/or delete files. Also, individual pixel values from any IMAGE may be displayed.

SYSTEM CONSIDERATIONS

Configuration: IMAGES was originally developed on Digital Equipment Corp. (PDP 11/45) and Control Data Corp. (CYBER 70 Model 74, Nos 1.3 operating System) equipment. However, the software is now in use at approximately twenty institutions using a variety of DEC, CDC, IBM, and Burroughs mainframes. The minimum compilers and hardware for implementation include a computer with a BASIC compiler, an assembler compiler and tape drive to read Landsat data and place it on disk, and alphanumeric CRT or hard-copy terminals. Most universities have these facilities; consequently, no departmental capital equipment expenditure is required. If a plotter and fortran compiler are available, then it is possible to use the optional plotting programs.

At the University of Georgia where much of the development has taken place, CDC BASIC Version 3.5 is used which conforms at PSR level 528 to the American National Standard for Minimal BASIC (ANSI). This is not an extremely "extended" BASIC, consequently, few have experienced difficulty implementing the software. Also, the software is basically self-contained, i.e. it makes no use of system dependent routines such as sorting etc. which might inhibit implementation elsewhere. Preliminary investigation of CDC requirements suggest all programs use less than 20K 60-bit words of core (or approximately 145K 8-bit bytes).

Costs: Classes generally have 20 to 30 students, however at U.C. Santa Barbara, as many as 70 use the system in a single quarter. The cost of running the system may be computed as 25 hours per student per quarter at $2.00 per hour, e.g. 25 students @ 25 hours @ $2.00 equals $1250.00 per quarter. This includes the cost of storing the Landsat images on disk for the quarter. More specific cost estimates per program are available [17]. The cost of acquiring IMAGES is $200 and includes output to 1600 BPI tape, listing, test images, and example sessions. Funds received are used to improve the system. All programs are functioning, however, the author may retain a program if documentation is in progress.

Experiences: Increased demand on the time-sharing system does slow down interactive work during the day, consequently, students often perform their analysis during the evening. A "keyword" version of IMAGES is envisioned which does not provide all the verbage necessary for the beginning student. The necessity of GETting, ATTACHing or SAVing files can be confusing to students. However, more extended BASIC compilers do this automatically using OPEN and CLOSE commands. Software limitations include the lack of a geometric rectification algorithm, statistical feature-separability measure, and unsupervised classification. These and other programs are being developed.

SUMMARY

IMAGES is relatively inexpensive to operate, is almost hardware independent and allows multiple users to interact with the system in a tutorial environment. Additional software development will improve its potential for effective remote sensing education.

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CORSE-81

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Digital Image Data Sets for Remote Sensing Instruction

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The author has used several sets of Landsat image segments and a set of simple image processing programs operating in batch mode to teach an introductory course in digital image analysis and classification. The image data sets contain only a small number of pixels and can be run quickly on most university computing systems. A number of image data sets derived from the raw spectral bands (smoothed data sets, band ratios and texture data sets) allows the student to examine and include these extracted variables in the classification process. Another data set consists of three registered Landsat image segments for three different dates so that the student may experiment with multitemporal data processing. The three Landsat scenes used in the class are described below and the image data sets available for class exercises are listed in Table 1.

Atikokan, Ontario. This May 9, 1975 image data set is centered on the western flank of the Canadian Shield and contains the entrance to the Quetico wilderness canoeing area north of Ely, Minnesota. Elements in the scene are two large open pit iron mines, timber clear cutting, areas of burned over forest, highways, lumbering roads, pipelines and hydro-electric transmission lines, and the town of Atikokan (population 6,000). The lakes in the scene have just broken up during spring thaw and a residual ice cover shows up in the center of several of the larger lakes.

Georgetown, South Carolina. Covering a portion of the Carolina coast this image subset (January 5, 1979) includes the industrial community of Georgetown (population 12,000), and the marine environments of Winyah Bay and the spartina tidal marsh at North Inlet. Visible in the scene are a newly formed spit at the entrance of North Inlet, the sand beaches lining the coast, a military airport south of Georgetown and reservoirs off of the Sampit River. Channelization within Winyah Bay, relic beach ridges, and the extensive southern pine forest cover can be clearly seen.

Eudora, Kansas. This image data set is comprised of registered scenes for three different dates (5/20/76, 6/26/76, 8/19/76). The scene is located on the flood plain associated with the Kansas River near the town of Eudora (population 2,000). The extensive agriculture on the floodplain consists of three dominant crops; winter wheat, corn and soybeans which are planted shortly after the harvest of the winter wheat sometime in early July. A segment of the flood plain has been extensively groundtruthed[1] and a map identifying the crop type for about four hundred of the fields is used in the analysis of these image data sets.

TABLE 1

DIGITAL IMAGE DATA SETS

Atikokan (200 x 480)

Spectral bands: 4,5,6,7,5+7

Georgetown (288 x 360)

Spectral bands: 4,5,6,7,5+7
Spectral bands smoothed: 4,5,6,7,5+7
Band ratios: 7/6, 7/5, 7/4, 6/5, 5/4
Texture bands (variance): 4,5,6,7,5+7
Texture bands (first derivative): 4,5,6,7,5+7

Eudora (116 x 130)

Spectral bands date 1: 4,5,6,7
Spectral bands date 2: 4,5,6,7
Spectral bands date 3: 4,5,6,7

Note: Values in parentheses indicate the size (row and column) of the image data set.

5+7 indicates the average of band 5 plus band 7

7/5 indicates the ratio of band 7 to band 5

The author's Fortran programs and the SAS setups listed below are the only programs needed to carry out the principal class exercises.

TABLE 2

STANDARD PROCESSING PROGRAMS AND SETUPS

Programs and Setups	Function
IHIST	Outputs a histogram and frequency table.
IREAD	Displays raw data values.
IGREY	Generates a brightness map.
ITRAIN	Extracts training field data values.
CLUST	Initiates a SAS cluster analysis.
DISCRIM	Initiates a SAS discriminant analysis.
IMAP	Produces a classified map.

Each of the programs can be used with an entire image data set or with any rectangular subset of the image data set. The mapping programs (IGREY and IMAP) automatically swath the output into 120 column map segments and allow for four character overprinting and the maximizing of grey levels for maps with fewer than 8 classes. Class intervals need not be continuous and unclassified sections of the map are printed as blanks. If only one class is selected for level slicing or theme extraction, the class is printed with the darkest overprint combination. The training field selection program (ITRAIN) will extract either rectangular or irregular shaped training fields for a maximum of 12 bands of image data. The classification program (IMAP) will accommodate 12 bands of image data as well.

The class exercises fall into three main areas:

1. A first look at Landsat data using the Atikokan image data sets.
2. An unsupervised classification of the Georgetown image data sets using the spectral, band ratio and texture image data sets.
3. A supervised classification of the Eudora image data sets using the four spectral bands for each of the three dates.

For the first exercise students generate histograms (IHIST) of each band of the image data set and use this information to create brightness maps (up to 8 levels using IGREY) and single class theme maps (water only, transportation only, urban areas only, etc.). IREAD allows the student to display small segments of raw data for an individual band. Comparison of the actual data values for various parts of the scene from one band to another band can then be made.

The unsupervised classification exercise uses ITRAIN, CLUST, and DISCRIM to derive the coefficients of the classification functions. IMAP is used to classify and map the entire image data set using the output from DISCRIM. Students can experiment with different combinations of the spectral, ratio and texture information to achieve the best classification. Training fields are selected with the aid of a Landsat color composite and a high altitude NASA aircraft photograph.

The supervised classification exercise depends on the student's ability to extract homogeneous features using ITRAIN. For the Eudora multitemporal images, this involves finding fields of wheat, corn and soybeans as well as forest, water and highway classes. The output from ITRAIN is used directly with several runs of DISCRIM in order to determine the effect of different dates. The comparison of the classification confusion tables from DISCRIM concludes the exercise; a classified map (IMAP) is optional. Additional programs are used by the students to facilitate the exercise requirements and to initiate individual student projects. These programs are listed in Tables 3 and 4.

TABLE 3

SPECIAL DISPLAY PROGRAMS

Program	Function
SYMVUI	Produces a perspective plot of an entire image data set or subset of the image data set.
SYMVUF	Produces a perspective plot of the grey level frequencies for any two band combination (feature space graph).
IPLOT	Outputs a single class or level slice on the Gould electrostatic plotter using .03 inch x .04 inch pixels. A number of slices can be color composited using Diazo.
ICOLOR	Produces three separation positives (cyan, magenta, and yellow printers) on the Gould plotter using the output from IMAP to produce a colored classification map.

TABLE 4

STATISTICAL AND TRANSFORMATION PROGRAMS

Program	Function
ICOR	Provides the linear correlation coefficient between two image data sets.
ILOCAL	Indicates the row and column registration of any number of control points between two image data sets of different dates using a neighborhood correlation matrix.
ITRANS	Outputs the coefficients for a least squares solution of the affine equations for image to image, image to map or image to airphoto registration.

Program ITRANS can be used to transform training field cartesian coordinates from an airphoto or map (using a digitizer or grid overlay) into the row and column coordinates of the Landsat image data sets. This allows for the selection of irregular shaped training fields of specific features for supervised classification.

Two principal problems have occurred in teaching this course. The students use an interactive editing system and personal libraries to complete their work. Output from the batch runs are returned to their work space and edited for subsequent runs. The output format from the author's programs are compatible from one run to the next but the output from the SAS runs require considerable editing or recopying. Programs are currently being written to replace the SAS programs in order to solve this problem.

The second problem is universally associated with many academic computing systems--poor turn-around times. This can severely limit the feedback and reinforcement derived from the exercises. Even with small image subsets the required computational time often places the runs at second or third priority in the processing queue. However, treating the class as a seminar and meeting once a week usually allows for enough time to obtain reasonable turnaround.

The four programs used to generate the data sets are listed in Table 5.

TABLE 5

PROGRAMS TO GENERATE IMAGE DATA SETS

Program	Function
IPACK	Selects an image segment from one or two files of a Landsat CCT, deskews[2] the image and prints a simple brightness map using equal class intervals. An option for smoothing[3] (low pass filter) and writing the data to mass storage is provided.
IRATIO	Produces band ratios[4] for any combinations of two bands and rescales the ratios to a 0-127 scale.
ITEX	Generates the variance[5] and the first derivative (maximum slope) of the grey levels values in a roving 3 x 3 neighborhood matrix applied to the image data set rescaling 0-127.
IREG	Using the control points established with ILOCAL and the coefficients from ITRANS this algorithm produces a registered data set based on nearest neighbor sampling.

Overall the class response to this particular approach has been quite positive. Students appreciate the "hands on" experience and are able to quickly grasp the fundamentals of digital image analysis. Examples of student exercises will be displayed in the evening poster session at CORSE 81.

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SOME CONSIDERATIONS IN LOW-COST IMAGE PROCESSING ON A UNIVERSITY MAIN FRAME

THE PENN STATE (ORSER) EXPERIENCE

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Introduction

The ORSER System is a comprehensive package of computer programs developed by the Office for Remote Sensing of Earth Resources (ORSER) at The Pennsylvania State University for analyzing various kinds of remotely sensed digital data. Its development began in 1970 with a dual purpose in mind:

a. To provide, for remote sensing analysts within the university community, an analytical system that could be operated from Remote Job Entry (RJE) teletypewriter terminals; and

b. To provide hands-on experience, through an Advanced Remote Sensing course, to graduate students, who could operate the system from card reader/fast line-printer stations at or remote from the Penn State Computation Center.

To facilitate this dual role, the system was developed in a modular fashion with each step of analysis being a program which generally accepts a tape of data and control cards or card-images as input and produces as output either another tape or some kind of character map on the line printer. For ease of conceptual understanding as well as computational efficiency, all programs are couched in a multivariate framework. This has made it possible for a number of different people to contribute to the system, often as part of a graduate student's thesis research. These developments have been under the direction of a faculty member and a systems analyst who have ensured that strict standards on uniformity of control card formats, documentation, and debugging are maintained.

Audience/Purpose

From its beginning, the ORSER System has been used as the hands-on backbone of a graduate level "Multispectral Remote Sensing" one-term course taught annually in the School of Forest Resources. This year, for the first time, it was used at the end of a senior-level undergraduate "Introduction to Remote Sensing" course taught by Dr. Wayne Myers in the School of Forest Resources.

The System has also been used in teaching a variety of short courses, ranging in length from a few days for small groups of remote sensing consultants with specific application interests to a 2-week course organized by NASA for regional and urban planners who had little or no previous exposure to remote sensing.

Capabilities

Although for instructional purposes we customarily work with relatively small areas of a Landsat scene (of the order of a few hundred pixels square), the ORSER System now has the capability of processing up to five-channel full Landsat scenes, or lesser widths of more channels. In addition, the System has the ability to read data from a wide variety of other satellites and aircraft and digitized sources. Programs are also available to allow merging (overlaying) of data, windowing, spanning adjacent data, data transformation, bounding of irregular areas, and geometric correction.

A number of programs are available in the System for conducting various kinds of image enhancements and supervised or unsupervised classifications. Most of these programs have default values for the parameters, allowing for a first look at the data with very little input needed from the user. Most of these programs optionally produce a character map on a line printer or store a compressed character map for later display. Finally, there are programs that will allow data in character map form to be displayed on a variety of devices following, if necessary, geometric correction.

A system of programs that will handle polygon data has recently been added. They will perform such operations as polygon-to-grid-format conversion, editing of digitizer data, overlaying of polygon data onto grid data for display purposes, and calculation of area statistics. The ZONAL system currently being added will provide the ability to aggregate classification results over externally defined geographic referencing units such as grid cells or polygons. Output will be a listing (file) of aggregated data by geounit. Such a file can be readily formatted for direct entry as an additional layer in a host information system where non-remote sensing information resides.

Costs

Costs of operating the system are dependent on the size of block processed and the type of analysis carried out. For instructional purposes, blocks are relatively small and, after the first subsetting, most programs will cost a dollar or so to run on our current accounting basis. Non-local users can access the System from about any kind of remote terminal if suitable contractual arrangements are made. The user must then, of course, pay the additional telephone charges. The complete ORSER System can also be purchased as Fortran code on computer-compatible tape for $3000.

Ease of Acquisition, Installation, and Use

The ORSER System has been acquired by about 40 organizations in the United States and some 8 foreign countries. Most of these have had large IBM computers, although the System has also been installed on large CDC, Honeywell, and Burroughs main frames. Ease of installation has varied, depending more on the ability of the installer than the particular computer configuration. Since all code is now in near-ANSI Fortran IV, the latest version should be easier to install than previous ones.

The System has been found relatively easy to use by undergraduate and graduate students and by short-course attendees. Typical run decks or "stems" are given in the "ORSER Users' Manual" (Turner et al. 1978) and card users can use these as a base or can be provided with these as a card deck to be modified by the user. Teletypewriter-terminal users can call stems for all programs from stored files and edit them. Comments indicating how JCL instructions should be changed are stored with the stems. All control cards are set up as a keyword followed by appropriate parameters in fixed format. Defaults are used extensively. Most programs can be successfully run with only a few control cards and users can then refine the results by modifying or adding control cards. Control cards are described in the Manual and many of them are common to several programs.

A user-friendly "front-end" to several of the ORSER programs has been developed at NASA/Goddard and has been used extensively in their training sessions. This "OCCULT System" is described in their "ORSER 'Hands-On' Training Manual" (National Aeronautics and Space Administration 1980) and the programs are available through COSMIC. At Penn State, we have used our Interact editing system to develop a similar procedure for all programs. The role of both of these "front-ends" is to allow the user to set up a run file (JCL and control cards) in a conversational manner and submit it for batch processing. They are not essential to the operation of the ORSER System.

General

Because of its modular construction, the ORSER System is suitable for all classes of remote sensing users. Although in a beginning course only 6 to 10 of the programs are generally used, the researcher has a set of about 35 programs available for his analyses. For training purposes, we have used everything from a small "canned" data set stored on disk to a BYOD approach.

Some of the advantages of teaching remote sensing techniques using ORSER software on a university main-frame computer are the following:

a. It is inexpensive relative to dedicated hardware systems for the casual user.

b. Maintenance and operations are someone else's (the Computation Center's) problems.

c. Many students will be somewhat familiar with the Operating System before entering the course.

d. Because of the ease of transporting the ORSER Software System, many students take it with them when employed, resulting in low-cost technology transfer.

e. The modularity of the System permits graduate students to add or modify programs without disturbance of the overall System.

f. The step-by-step nature of using the System means that students end up with a much better understanding of what the computer is doing, as compared with a "black-box" hardware system.

There are a few disadvantages in this instructional approach:

a. Students are not exposed to state-of-the-art hardware with which they may be faced when employed.

b. Line-printer maps are less easy to interpret than those produced on specialized devices and may constitute a handicap for some students.

c. Similarly, students may spend an inordinate amount of time correcting input format errors, etc., particularly if one of the front-end systems is not available.

Conclusion

It has been our experience at Penn State that the ORSER System as implemented on the University Computation Center's IBM main frame has proved to be an exceptionally useful mechanism for instructing the present and future remote sensing community in the theory and practice of automated analysis of digitized data. This experience has been replicated at a number of other institutions.

Although there are some limitations to this approach, it works very well in our instructional and computing environment.

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THE REMOTE ANALYSIS STATION (RAS)
AS AN INSTRUCTIONAL SYSTEM

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Introduction

NASA established a very successful program with the Environmental Research Institute of Michigan (ERIM) on 20 December 1979. Its objective was to investigate methods of making Landsat technology readily available to a broader set of private sector firms through local community colleges.

To achieve the desired objective — i.e., the transfer of Landsat technology - the program applies a network where the major participants are NASA, university or research institutes, community colleges, and local private and public organizations. The methodology employed by the program gives local users an opportunity to obtain "hands-on" training in Landsat data analysis techniques, using a desk-top, interactive "Remote Analysis Station" (RAS). The RAS communicates with a central computing facility via telephone lines, and provides for generation of land-cover maps and data products via remote command.

The RAS System

The Remote Analysis Station (RAS) consists of a color CRT imagery display, with alphanumeric overwrite and keyboard, as well as a cursor controller and modem. This portable station can communicate via modem and dial-up telephone with a host computer at 1200 baud or it can be hardwired to a host computer at 9600 baud. The station contains a Z80 microcomputer which controls the display refresh memory and remote station processing.

Landsat data is displayed as three-band false-color imagery, one-band color-sliced imagery, or color-coded processed imagery. Although the display memory routinely operates at 256 x 256 picture elements, a display resolution of 128 x 128 can be selected to fill the display faster. In the false color mode the computer packs the data into one 8-bit character (3 bits for red, 3 bits for green, and 2 bits for blue). When the host is not sending pictorial information the characters sent are in ordinary ASCII code.

The RAS features the following capabilities:

- Low cost - the station can be assembled from readily available hardware for less than $20,000
- System portability - the user supplies only electrical outlets and telephone
- Interactive control via a simple, menu-driven language
- Dial-up access to host computer with selectable trade-off between image viewing speed and quality (resolution)
- Histogram display, categorization accuracy tables, and results of category separation analysis
- Categorized image display in colors selected from list with over 40 options
- Edit colors within areas enclosed via cursor - 'digital air brush'
- Generation of land cover tabulations directly from display by designating boundary of area with cursor
- Display of selected map categories over false color images
- Input of image and map control points for geometric correction
- Generate electronic service request for initial Landsat files, and subsequent image and data products

Integration with the Host Computer

During this technology transfer program, the host computer for the RAS has been the PDP-11/70 computer in ERIM's Earth Resources Data Center (ERDC). Figure 1 illustrates the RAS linked to its host via phone line and modem. Virtually any 16-bit (or larger) computer which supports FORTRAN, tape, and disk operation is adequate as a host.

Summary of Operational Steps

The events described on the flow chart (Figure 2) are those typically used by RAS operators to process Landsat data. The RAS user may initiate a project at several different stages in the processing path. Many users begin a project with a subscene which has been geometrically corrected. Others who are more cost conscious process a raw Landsat subscene and perform a geometric correction after the creation of the categorized file.

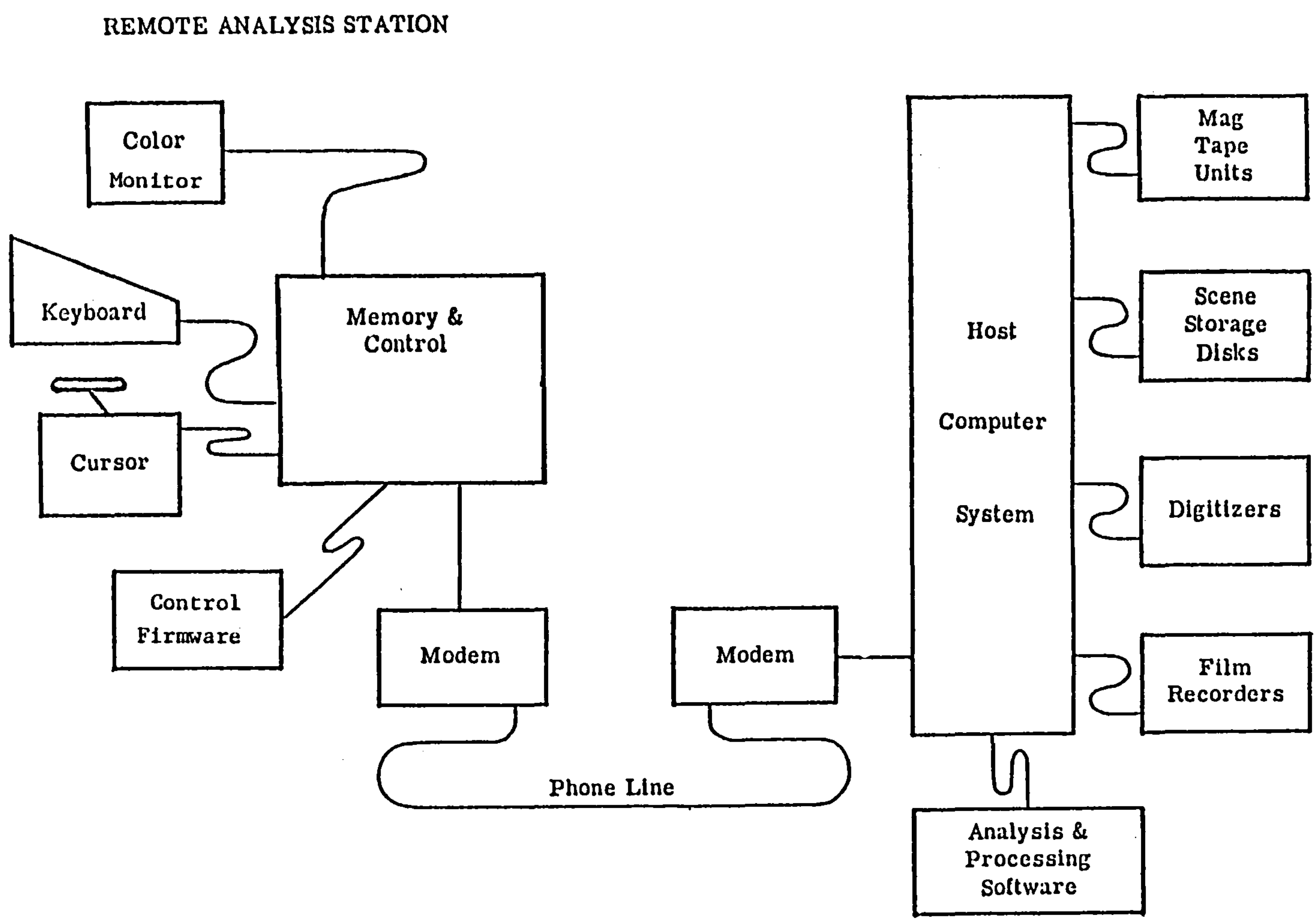

Figure 2. RAS and Host Computer

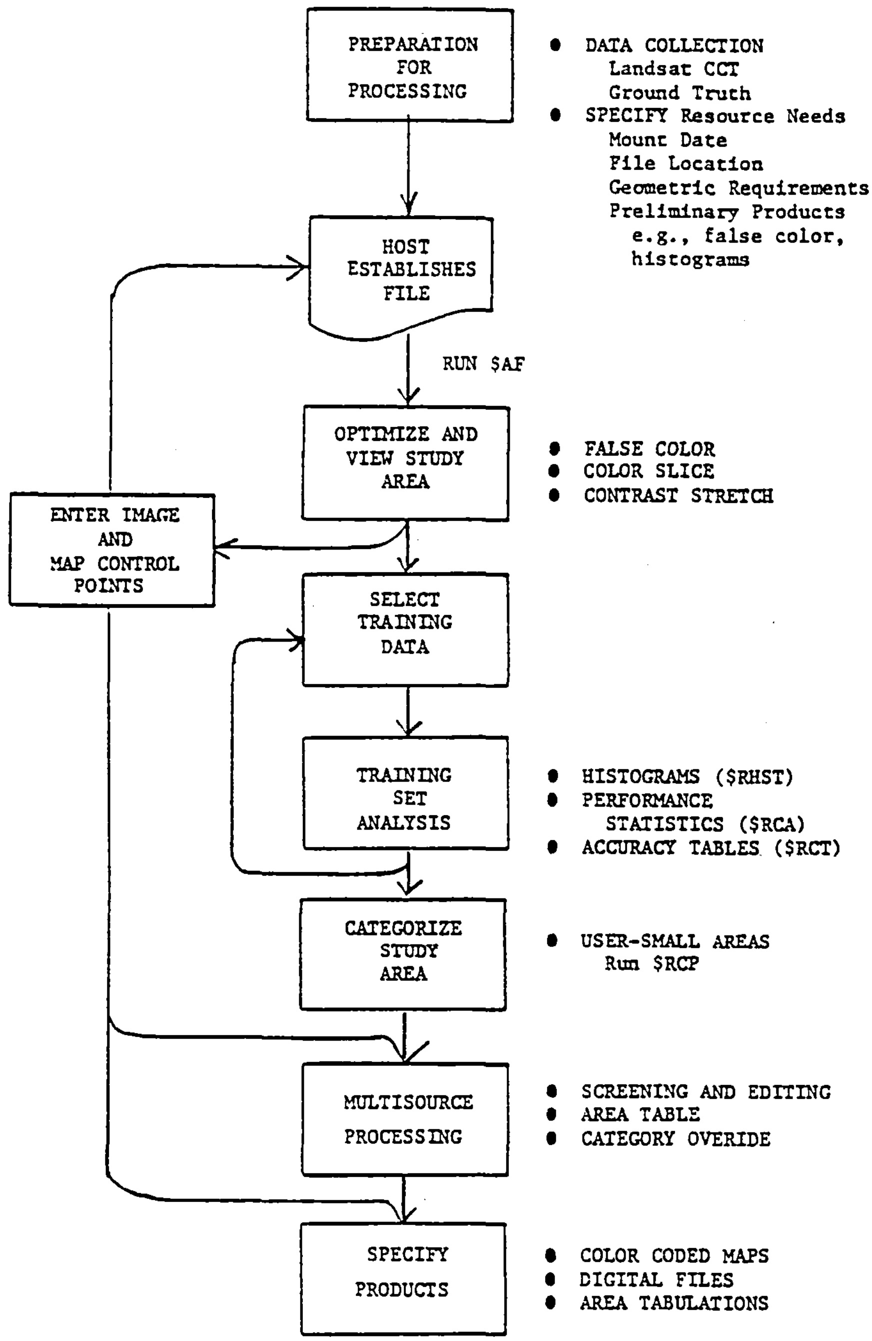

Figure 3. Flowchart Illustrating Steps In Processing A Subscene Using RAS Terminal.

RAS features interactive control via a simple, menu-driven language. Table 1 lists the present 6-option menu with sub-menus and the most frequently used off-line programs. After the user has logged in, operation is initiated by display of the six major options. To call one of the sub-menus, the user simply enters the appropriate letter, e.g., "R" for RADIOMETRIC and the corresponding options, false color, color slice, contrast etc., appear.

Conclusion

Transfer efforts during the 1980's have demonstrated that recent developments in computer technology now make it possible for the private sector to provide high-quality Landsat products and services, using a desk-top computer terminal, at a low initial investment of about $20K. It also shows that community colleges as well as private and public organizations, all of which are readily available to the local user community, can join in cooperative efforts to deliver the needed training in the use of the terminals and the application of Landsat technology.

Program emphasis during 1981 is directed at: continuing cooperative technology transfer programs to involve more colleges, identifying alternative sources for the RAS terminals, establishing new sources for the host computer service, upgrading the operational capability of terminal and host software to simplify operations and to add capability to manipulate other data sources, and upgrading training materials.

1. QUIT (Q)

2. RADIOMETRIC OPTIONS (R)
   1 FALSE COLOR
   2 COLOR SLICE
   3 CONTRAST
   4 CATEGORIZE

3. GEOMETRIC OPTIONS (G)
   1 LOCATION
   2 SCALE
   3 IMAGE CONTROL POINTS

4. TRAINING DATA (T)
   ENTER TRAINING SET NUMBER?
   ENTER UPPER LEFT CORNER
   ENTER UPPER RIGHT CORNER
   ENTER LOWER RIGHT CORNER
   ENTER LOWER LEFT CORNER
   NAME?
   GROUP NUMBER & COLOR?

5. MULTISOURCE PROCESSING (M)
   1 CATEGORICAL DISPLAY
   2 CATEGORICAL OVERIDE
   3 CO-OCCURRENCES
   4 EDIT
   5 AREA TABLES

6. UTILITIES (U)
   1 PAUSE
   2 STOP

7. FREQUENTLY USED OFF-LINE PROGRAMS
   1 TRAINING SET HISTOGRAMS ($RHST)
   2 REMOTE CATEGORICAL ANALYSIS ($RCA)
   3 ACCURACY TABLES ($RCT)
   4 REMOTE CATEGORICAL PROCESSING ($RCP)
   5 ELECTRONIC SERVICE REQUEST ($ESR)
   6 TEXT EDITOR (EDI)

Table 1. RAS 6-Option Menu and Frequently Used Off-line Programs.

Discussion

1. What is the availability of these software systems?

   Jensen: Available at present and asking price is $200. Considering offering through COSMIC, but then the price would probably be more than $1000.

   Eyton: Software not available until middle of next year.

2. Since your (JENSEN's) system is in BASIC, can it be used in smaller mini-computers such as the APPLE?

   Jensen: The software has been put on a Z-80 based system, but not sure about others.

3. Does any of the panel have software which will allow statistical files to be integrated with other statistical files?

   Williams: System does not.

   Eyton: System does have capability because of the inherent step nature of the design.

   Turner: It is possible on ORSER.

   Rogers: Possible on ERIM system (RAS), but with some limitations.

4. What software is available for processing full frames of Landsat data?

   LARSYS, VICAR and probably several more.

5. Have the existing software systems planned for the impact of the Thematic Mapper?

   Turner: ORSER is being planned to handle a maximum of 24 channels when upgraded.

   Rogers: ERIM software can handle that many channels at present.

Participants in University Main Frame Discussion

BALEJA, John
BAUMANN, Paul
BOYD, Ron
DAHLBERG, Dick
EYTON, J. ronald
FORD, Jack
HENNIG, Thomas A.
HENRY, Jim
HILL-ROWLEY, Richard
HOPKINS, Paul
JENSEN, John R.
LOUGEAY, Ray
LUMAN, Don
LUSCH, David P.
MCCOY, Roger M.
MCINTOSH, Tom
MONSEBROTEN, Dale
MORROW-JONES, Hazel A.
MYERS, Wayne L.
RICHARDSON, Kevin
TURNER, Brian
WILLIAMS, T.H, Lee

Session 5-b

Low-Cost Digital Image Processing on a Micro-Processor Based System

Session Highlights:

Three papers were presented during this session which was chaired by Harvey Wagner, Technicolor Graphic Services, Inc. The session chairman summarized the session as follows:

"It was highly gratifying to witness the expansion of interest in very low cost digital image analysis devices which the participants in this session evidenced. It is now obvious that the current boom in personal computing equipment is slowly but steadily providing an equipment base on which Remote Sensing educators and researchers can draw to create a new generation of image display and processing devices for teaching and research purposes.

"Throughout the discussion which we conducted at this session, there was expressed a clear and urgent message to the Remote Sensing community that more digital equipment at a much lower price (less than $10,000) is needed NOW, and more and easier to use teaching materials in the field of digital image analysis are desperately need.

"The presence of representatives from four different organizations that are currently involved in the development or marketing of low cost digital image analysis systems served to provide the group with the kinds of information and insight in this field which many of the participants are not often exposed to.

"I personally found this session to be both exciting and informative. I felt that it pointed to a significant gap in our current Remote Sensing teaching programs and the ways to remedy these shortcomings. I hope that more sessions like this one are made a part of future Remote Sensing conferences and look forward to attending them in the not too distant future."

Session Reporter was Dan Krizan, Purdue University.

CORSE-81

The 1981 Conference On Remote Sensing Education
May 18-22, 1981 Session No. 5B

APPLE IMAGE PROCESSING EDUCATOR

Prepared For

Eastern Regional Remote Sensing Applications Center
NASA/Goddard Space Flight Center
Greenbelt MD 20771

by

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ABSTRACT

A software system design is proposed and demonstrated with pilot-project software. The system permits the Apple II microcomputer to be used for personalized computer-assisted instruction (CAI) in the digital image processing of Landsat images. The programs provide data input, menu selection, graphic and hard-copy displays, and both general and detailed instructions. The pilot-project results are considered to be successful indicators of the capabilities and limits of microcomputers for digital image processing education.

INTRODUCTION

Many advertisments and popular articles discuss the ability of one or another microcomputer to process data and display results. The microcomputer is often shown in the process of teaching something to school-age children. Trade magazines also show the use of microcomputers as technical training or educational devices for college students or adults.

The Eastern Regional Remote Sensing Applications Center (ERRSAC) of the National Aeronautics and Space Administration (NASA) at Goddard Space Flight Center (GSFC) uses computers for digital image processing in remote sensing projects and for training in digital (computer-assisted) image processing. The computers are used 1) as production or research tools, and 2) as educational tools for group presentations and individual learning. Considerable one-on-one computer-assisted instruction (CAI) in digital remote sensing concepts and practices could be easily achieved using a teaching system implemented on a small microcomputer.

The Apple II microcomputer, with its color graphics capability, is considered to be a suitable training aid. The newly released Apple III is probably even more suitable, but not enough is known of its capabilities at this time. Because of its educational rather than research or production aspect, the proposed system has been given the name "Apple Image Processing Educator" (AIPE).

It is expected that the AIPE system, implemented at ERRSAC, would assume some of the work load currently carried by two very heavily used production systems. It should also reduce some of the work load of ERRSAC staff who make presentations during the training sessions. It would reduce the need for staff to travel to distant locations for offsite training sessions and presentations.

It is also expected that the AIPE system, implemented at a university, college, or agency department using remote sensing technology, would aid in the introduction of digital technology to members of those units in a cost-effective manner.

New users, those with little or no prior digital image processing experience, are expected to make most use of the AIPE system. The proposed system could be used as one part of a multimedia training session. Graduates of the AIPE system would be expected to quickly and easily adapt to research- and/or production-level digital image processing systems.

DESIGN

The AIPE system must be user friendly. It should ease the introduction of the new user to the technical aspects of digital image processing. Several image processing systems already exist that are very sophisticated in terms of their ability to perform digital image processing, but that are very difficult for the new user to use. AIPE should be an instructional system, not a production system. The AIPE system is intended to stress CAI using simulation rather than multipath questions and answers.

The design criteria for the AIPE system are being met by the following system design features:

- Implementation on the Apple II microcomputer with a minifloppy disk drive.
  - The computer uses color graphics.
  - The computer is sufficiently small so that new users are not intimidated by the computer.
  - The computer is inexpensive enough so that several can be maintained within training laboratories.
  - Data and programs are stored on the disk for ease of loading into computer memory.
- A menu program that provides the new user with:
  - A color graphics banner to "WELCOME" him/her to the system.
  - General system information.
  - A menu of image processing programs.
  - Optional short explanations for each program.
  - Optional step-by-step demonstration of each image processing procedure.
  - Automatic loading of instructional or image processing programs from disk by the menu program.
- A set of image processing programs that perform most image processing functions.
- An instruction program for each image processing program.
- User choice of image data files for analysis.
- Automatic disk storage of user image and statistical files, under user-selected names.

PILOT PROJECTS

Pilot project computer programs have been written to test various aspects and features of the AIPE system. The computer programs have been written in either Integer BASIC or Extended BASIC. The programs have successfully tested the following image processing procedures: 1) data transfer from another computer system that can read original data tapes; 2) color-coded density slicing of each channel and of the "norm" of all channels; 3) producing a line-printer version of any color-coded image; 4) producing a disk-file copy of any color-coded image; 5) statistical comparisons of color-coded images; 6) extracting training areas to obtain sample statistical data; and 7) graphic presentation of pixel statistics for image traverses. The pilot projects have been very successful in displaying the capabilities of a small microcomputer in processing remote sensing image data.

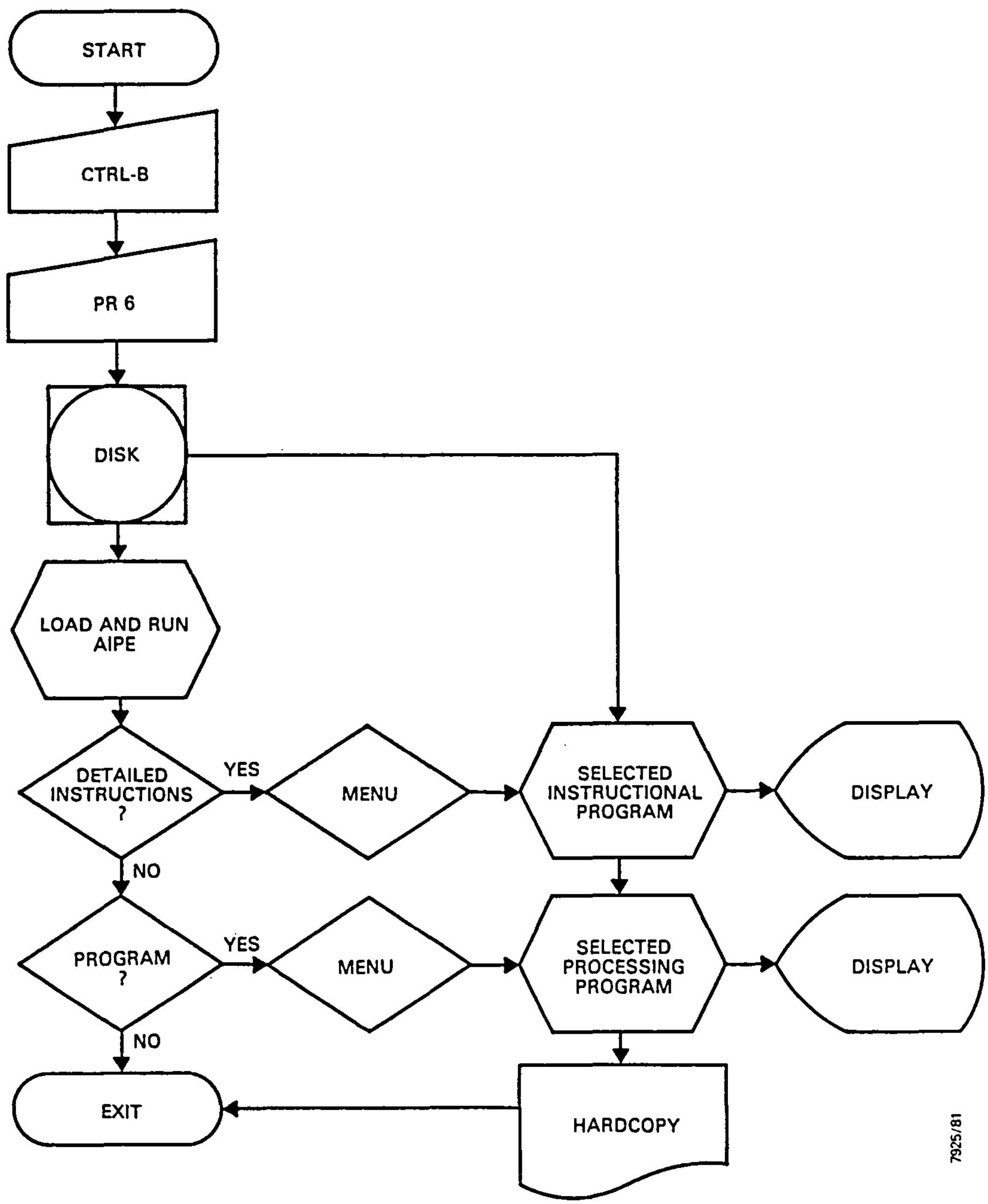
The pilot projects have demonstrated that the Apple II has both the hardware and software capabilities for processing remotely sensed multispectral data in a teaching or training mode. The Apple II can store in memory a 40 x 40 x 4 (line-sample-channel) image from a disk file in about 12 seconds. It can display a 40 x 40 image in up to 15 colors in about 45 seconds. Connected to a 1200-baud rate lineprinter, it can produce a hard copy of any color-coded image in about 1 minute. Data processing may be speeded up by the use of optimized Integer BASIC code rather than Extended BASIC. Training areas can be selected within the image using game controls. Keyboard entry in response to prompts is easy and efficient, and can be "idiot-proof." Programs and data sets can be loaded from a menu or directly from the keyboard.

CONCLUDING REMARKS

Tests using several pilot-project computer programs have successfully demonstrated that small microcomputers have the capability to process Landsat digital image data. The available memory is smaller and the processing is slower than that of miniframe or mainframe computers (HP-3000 or IBM 370), but a microcomputer (an Apple II) will process the data and display the results in a reasonable time. The Apple II (or any of several other similar microcomputers) is affordable by most departments and agencies using remote sensing digital technology.

The AIPE system for CAI has been presented in its present incomplete form to participants in the 1981 Conference on Remote Sensing Education to provide potential users with a chance to evaluate the system and to suggest additional options and features. Comments and suggestions are welcome.

Flowchart showing Relationships of Menu, Instructional, and Image Processing Programs in the AIPE System.



NASA

CORSE-81

The 1981 Conference On Remote Sensing Education
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Digital Processing of Landsat Data with a Microprocessor System, its role in environmental and natural resource education at the undergraduate level.*

The development of an environmental and natural resource program within the Department of Zoology at Howard University faces major obstacles, experienced commonly by colleagues at other academic institutions throughout the country. Funding to support a viable field and laboratory program, development of good undergraduate courses in this discipline, generating interest among faculty for an interdisciplinary program, and guaranteeing reliable logistic support from the university administration, are some of the obstacles to overcome.

Nonetheless, development of such a program has centered around a rather common relationship, the association of the faculty with another research institution. In this case, development of a low cost digital processing facility, through funding at the Smithsonian Institution's National Zoo, is the important catalyst for initiating the environmental and natural resource program at Howard University.

Briefly, the approach within the Department of Zoology has been to provide students with a broad understanding of environmental sciences, through undergraduate courses, so that highly motivated students can be identified. Then it is possible to have these students participate in independent research through the digital processing facility at the National Zoo.

The microprocessor is part of the IMPAC, (Image Analysis Package for Microcomputers), available through Egbert Scientific Software. The zoo facility, IMAGES,(Image Analysis and Graphic Facility for Ecological Studies), utilizes the Smithsonian Institution's Honeywell 6066 as a mainframe.

IMPAC provides full digital computer analytic capabilities and is capable of creating and displaying full color multispectral classification maps of Landsat data. Full statistical analysis capabilities including histogram generation, image ratioing and correction are available. Interactive digital systems such as IMPAC, are a cost effective image transformation process. A complete IMPAC system with computer, terminal, printer, color TV, and disk memory sells for $15,000.

IMPAC programs are available on a single magnetic disk and ready to run on a microcomputer. The following standard analysis programs are included:

- Data Input/Output
- Gray Scale and Map Build
- Image Data Analysis (training classification)
- Ratio and Transformation Analysis
- Parameter Alteration

The IMPAC system refers to the IMPAC program package together with the microcomputer and its accessories on which IMPAC runs. The basic IMPAC system consists of the following components:

- IMPAC software package
- CP/M and CBASIC systems software packages
- Microcomputer
- Disk memory system
- Color video image system
- Color TV video display
- Alphanumeric video terminal with keyboard
- Serial line printer
- IMPAC communications controller with connecting cables
- Acoustic coupled modem

The most important component of the IMPAC system is the microcomputer. It is the development of these very low cost computer systems, based on microprocessors, that makes IMPAC possible. The microprocessor used for IMPAC is the Intel 8080.

The microcomputer is directly controlled by the CP/M disk operating software. This program controls all data transfers within the computer and communicates with the disk memory, video terminal, and printer. CBASIC is a BASIC language compiler which communicates with both CP/M and IMPAC. CBASIC performs language translation functions allowing interaction of the other programs. The microcomputer used for IMPAC is the Vector MZ, manufactured by Vector Graphics, Inc. which includes an integral disk memory system with two disk drive units.

The alphanumeric video terminal serves as the primary communication devise between the user and the computer. Requests for instructions are printed on the video screen by IMPAC, and one enters simple commands on the terminal keyboard. All messages printed by IMPAC are in plain language as opposed to the abbreviations and symbols often encountered with other computer systems. One not need any special computer skills to use this system, making it very useful as a teaching tool.

Students can participate on current research activities that include tropical forest studies and local environmental analysis of the Potomac/Chesapeake Bay ecosystem. Students are encouraged to conduct field work, which is a mechanism for gathering ground truth.

Although in its infancy stage, this program has enormous potential. Perhaps most important, this technology is available at one of the nations foremost black institutions, and will, with continued support, provide excellent career opportunity for minority students in the environmental and natural resource areas. Development of a successful program requires further funding for undergraduate support including laboratory equipment, field equipment, renovation of lab facilities, and travel.

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NASA

CORSE-81

The 1981 Conference On Remote Sensing Education
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INTERACTIVE CAPABILITIES: BETWEEN UNACCEPTABLE AND UNNECESSARY

by
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The kind of system considered in this paper is a very low cost interactive image analysis computer system suitable for use in education, research, or operational remote sensing applications. The system should be centered around a high quality image display through which the analyst can use photointerpretation skills to evaluate and alter computer mapping or classification calculations. The definition of acceptable capabilitites for such a system must take into account the needs of the image analyst balanced with current state-of-the-art technology and cost. For this paper I have tried to define a range of acceptable capabilities based primarily on image analysis requirements, but tempered occassionally by cost and technology constraints.

These capabilities range between acceptable and desirable. I consider a system with more limited capabilities to be unacceptable, and one with more extended capabilities to be unnecessary for most applications. This is not to say that some applications do not require capabilities beyond the desirable range. However, experience at several installations has shown that very extensive capabilities are seldom used and in some cases actually detract from the system's utility.

Interactive image analysis system capabilities can be defined in terms of several specific system parameters. The system cost, even though not really a capability, is certainly an important parameter. For educational purposes a system cost between $10,000 and $20,000 might be considered acceptable. This amount of money is not unreasonable for the purchase of computer equipment by a school or individual department. Once the system cost is within the range of possibilities then you can start to consider other system parameters.

The basis of the image analysis system is the computer around which it is built. The important parameters dependent on the computer itself are; processing memory capacity, speed of response, on-line disk memory capacity for image storage, ease of interfacing with other devices for data transfer, and availability of low cost accessories for expansion. Within the acceptable price range the latest generation of microcomputers can easily provide parameters over the full range between acceptable and desirable. Stand alone minicomputer systems are still too expensive, and implementing an interactive system with a large mainframe computer can cost more and produce less acceptable results than with a stand alone microcomputer.

The second major device for the image analysis system is the interactive image display device. With today's technology there is only one suitable device, and that is a video or TV based image display. The capabilities provided by a video image display system are excellent, if not essential, for any interactive system. The specific parameters of interest for the image display system are; image size measured in number of pixels (picture elements) per line by the number of lines, and number of gray levels or colors per pixel. Video image display devices currently available for microcomputers cover the full range between acceptable and desirable.

Additional devices are also necessary to make up a usable image analysis system. Devices are needed for analyst input such as a keyboard, track ball, joystick, or digitizer pad. Also, output devices are needed such as an alphanumeric video terminal, printer, plotter, or even a color image printing device. Finally, devices are needed to input and output image data such as a way to read LANDSAT computer tapes or a digitizer for photographs and maps.

Some combination of all of these devices or pieces of "hardware" is required to make up an image analysis system. However, all of the hardware must work together under the control of one or more computer programs or "software". It is also possible for the software to make it appear as though some of the hardware parameters have been changed. For example, through the use of a series of programs which automatically swap in and out of the computer, the processing memory capacity of a computer can be made to appear much larger than it really is. Thus, in order to define the parameters for a complete system both the hardware and the software must be considered.

A set of system parameters which takes into account both hardware and software can be defined in terms of your analysis requirements. A list of such parameters is given in Table 1, together with my choices for acceptable and desirable parameter values.

The parameters listed in Table 1 reflect several basic system operations. For example, you must be able to input LANDSAT data and/or digitize photographs. At present tape drives to read LANDSAT tapes will cost more than an entire image analysis system. A very good solution is to use your school's large computer to read segments from the LANDSAT tapes, and then transfer the data to the microcomputer via a telephone line and modem. A useful, and low cost, method to input photographic data to the image analysis system is through a television camera and digitizer circuit inside the microcomputer.

The size of each image segment is one of the most important parameters for the entire image analysis system. The video image display device and computer disk memory devices must have enough capacity to support the desired image size. Also, the time required to process the image increases with image size. Most cost performance trade offs are made with respect to the image segment size. However, the tendency to increase the image size into the unnecessary range is also one of the most often encountered problems.

If we consider a system which operates on an image segment of 200 by 300 pixels, then each image will contain 60,000 pixels and with LANDSAT data will cover approximately 17 by 16 kilometers. While performing supervised training and classification this provides a good statistical sample and good land area coverage. With current video technology each pixel can be visually identified. This size is almost ideal during interactive analysis in education and research applications. When much larger areas need to be mapped, then a bulk classification approach using signatures derived during small segment interactive analysis is desirable.

The real power of an interactive image analysis system is its ability to rapidly accept analyst inputs and display the results of numeric calculations such as in supervised training and classification. Thus, the speed with which the computer responds to interactive controls is very important. A desirable response time for a 4 spectral band classification should be measured in seconds.

It is possible today to build an interactive system with capabilities within the range discussed here, for a price that is also within the acceptable range. Photo 1 shows a microcomputer based interactive system that provides mid range analysis capabilities for a mid range price. This system has been operational since 1979. It and other similar systems are commercially available.

ACCEPTABLE	PARAMETER	DESIRABLE
64 by 64 Pixels	Image Display Size	200 by 300 Pixels
16 X 1 Image	Gray Levels or Colors	16 X 3 Images
Level Slice	Image Display Convert	Enhancement
4	No. of Spectral Bands	16
64 Levels	Pixel Precision	255 Levels
Via Telephone	LANDSAT Input	Direct Tape
TV Camera	Photo Input	TV + Scanner
Supervised	Classification	Supervised + Cluster
Parallelepiped	Classifier	Several
2 Minutes	4 Band Classify	30 Seconds
16	No. of Classes	32
Conflict Class	Resolve Conflicts	Maximum Probability
Histograms	Statistics	Hist. + Scattergrams
Ratios	Transformations	Several
Keyboard	Analyst Input	Keyboard + Joystick
Printer	Analysis Output	Printer + Plotter
$10,000 to $20,000	System Cost	$1.98

TABLE 1

Parameters representing the capabilities of a low cost interactive image analysis computer system. A system with parameters between the acceptable and desirable is considered suitable for most education and research applications.

PHOTO 1

Example microcomputer based interactive image analysis system with capabilities and cost approximately in the middle of the range shown in Table 1. Equipment shown is; left front - communications switch unit, left rear - printer, middle - alphanumeric video terminal with input keyboard, right top - color video image display, and right bottom - microcomputer with built in disk memory.

Discussion

I. Classification algorithms

a. users need to know what the algorithms are doing; one shouldn't apply a classification algorithm while being ignorant of basic principles of remote sensing; understand the function of the algorithm

b. determine an appropriate balance between the use of classification algorithms and an interactive capability which suits your needs

c. needs for a given level of accuracy are different for teaching and research

II. Other micro-processor systems can be applied to image processing (e.g. Radio Shack TRS 80). Incorporation of software from the Apple system is possible but rather extensive revisions may be required.

III. The group discussed experiences in data transfer between microprocessor and mainframe systems including data compression techniques.

Participants in Discussion on Micro-Processor Based System

BARNETT, Albert P.
BAUCOM, Thomas
BRAND, Richard
BROPHY, David M.
BRUZEWICZ, Andrew
CORLISS, Bruce .
DODSON, Russ
EGBERT, Dwight D.
GREEN, Ken
HARNAPP, Vern
HARRIS, Jasper L.
HOFFER, Roger
HOPPIN, Richard A.
JOHNSON, Evert W.
KASILE, Joseph D.
KIEFER, Ralph W.
KRIZAN, Don
LEUNG, Samuel S.
LEWIS, A.J.
LINDENLAUB, John
LIU, Calvin
LUDWIG, Gail
MANO, Jo Margaret
MCLAREN, Doug
NICHOLS, Woodrow W. Jr.
O'BRIEN, Neal R.
RAWDEN, Fiske
RIOS, Julio C.
SOONG, Yin S.
WAGNER, Harvey
WELCH, Roy
WHITEFORD, Gary
WILSON, Len
WOODS, Edmund

Session 5-C

Digital Image Processing on a Small Computer System

Highlights:

The session chairman, Ronald Danielson from the University of Santa Clara, summarized the discussion as follows:

From the presentations and comments made, it is apparent that there are software packages available for minicomputer systems which will provide the functional capability for educational use of image analysis techniques. The major problems are matching those packages to the hardware configurations available, and maintaining that match as the remote sensing organization's demands grow. In addition, current developments in integrated circuits and communication technology are certain to have major impacts on these activities in the next five years. It should prove to be an exciting and fruitful period.

Two presentations were made, one by the session chairman Ron Danielson and the other by Neil Weber of Murray State University. Summaries of both are reprinted on the following pages. The session reporter was Sarah Nunke, Purdue University.

CORSE-81

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May 18-22, 1981 Session No. 5c

SELECTING AN IMAGE ANALYSIS MINICOMPUTER SYSTEM

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1. Introduction

Selecting a minicomputer system to use as a basis for an image analysis computer facility involves weighing a number of different factors. The particular factors relevant in any specific situation depend on whether the user organization will be procuring a new computer or selecting an existing facility to serve as an image analysis host. Thus some of the topics discussed below may not need to be considered in every situation.

If there will be either a large volume of images or large sized images processed, a mainframe facility should also be selected to allow offloading of the slower image analysis tasks from the minicomputer to achieve reasonable response times. The factors in this paper are relevant in selecting this facility, as well.

Several considerations not directly related to hardware or software should also be weighed in selecting a host computer system. The apparent flexibility of the computer center staff, and their encouragement of innovation, are related considerations. Obviously, an open, cooperative attitude will improve the possibilities for successful operation.

For a new computer, existence of similar systems on campus (and hence of local experience and expertise) is a plus. The availability of the host processor to a broad spectrum of potential user organizations also may be important, as it allows for cost sharing.

2. Image Analysis Software

Few organizations are in a position to develop their own image analysis software, and must rely instead on implementing an existing software package on their computer. If particular software capabilities are desired, the corresponding choice of package may dictate the configuration of minicomputer hardware and operating system, since most packages are written for a single combination. Even if this is not the case, possible image analysis packages should be reviewed in advance, as they may have significant impact on the decision on which hardware to select. Software packages should be evaluated according to the functions they provide and the range of peripherals (displays, digitizers, etc.) they support.

User organizations without programming staff will probably require programming support during installation, in both FORTRAN and assembly languages. Even users with programming skills may require such assistance. The cost and availability of such services must be considered in evaluating any particular facility or configuration. Note that this type of assistance may be required periodically to insure compatibility with new versions of the operating system.

3. Computer Facilities

Table I summarizes the factors which should be examined in evaluating the hardware of a potential host installation. Each is described in more detail below. In general, the more of any resource (faster CPU, more memory or disk storage) available on a system, the greater its suitability as an image analysis host processor. It is important to determine both the current (or initial) number of peripheral devices (disk or tape drives, terminals) and maximum number possible for each candidate system, as this greatly affects expandability.

3.1. Central Processing Unit (CPU)

Determine the manufacturer and model number of the CPU, as well as its relative performance in that manufacturer's product line. For minicomputer systems, the presence of floating point (real number) hardware will significantly speed up many operations.

3.2. Operating System and Languages

The particular operating system under which the computer is running should be noted. As mentioned, most software packages are designed for a particular CPU/operating system combination. The amount of effort required to install a software package under another operating system may be prohibitive. The programming languages available on the system should also be indicated. Most image analysis software is written in FORTRAN IV; this language is essential. Other languages may be desirable, or required by certain software packages.

Table I
Summary of Major Factors in Computer Selection

Computer Facilities
- central processing unit
- operating system and languages
- main memory
- disk storage
- tape drives
- hardcopy output
- other peripherals

Operational Environment
- accessibility
- resource limitations
- operational support
- cost

Implementation Support

Miscellaneous Factors
- politics
- other potential users

3.3. Main Memory

The number of bytes (or words) of main memory is an important consideration. As for peripherals, the maximum amount of memory a system may have should be noted, along with the current amount. The maximum possible program size should also be checked. These factors determine the ease with which a system may deal with large amounts of data, and how many simultaneous users the system may support.

3.4. Disk Storage

The availability of large amounts of on-line disk storage is important in image analysis work; a full Landsat scene occupies about 30 million bytes. The amount of disk storage also affects the suitability of a particular computer for Geographic Information Systems (GIS) use. The capacity (bytes or words) and number of units of each type of disk attached to the system should be determined, as well as whether the recording medium is removable. Removable media allow users to purchase a pack dedicated to their use, and mount it only when their programs are running.

3.5. Tape Drives

Magnetic tapes are the primary medium for transfer and archival storage of imagery. Characteristics of tape drives include number of tracks (seven or nine), recording density (800, 1600, or 6250 bits per inch (BPI), or 800/1600 dual density), and tape speed (45, 75, or 125 inches per second (ips)). Nine track tapes are preferable to seven track, and it is advantageous to have both 800 and 1600 BPI capability on a system. Faster tapes (higher ips) speed input and output of image data.

3.6. Hardcopy Output Devices

The speed (lines per minute) and printer type (chain or drum, laser, ink-jet, or dot matrix) of line printers attached to the system should be indicated. Some dot matrix printers are also usable as plotters, a desirable capability. In such cases, the number of dots per inch and whether or not the printers are electrostatic should be recorded. Also, the presence of any drum or flatbed plotters should be noted as an advantage.

3.7. Other Peripherals

The presence of (or potential for adding) one or more relatively uncommon peripheral devices may be an overwhelming consideration in selecting an image analysis host system. An array processor can greatly speed computations for classification and clustering algorithms. Color or black-and-white graphics terminals can aid in control point selection and image data review. Digital film recorders are useful for producing final output products. Digitizers are desirable for inputting boundaries.

4. Operational Environment

The particular operational characteristics of an installation determine, to a great extent, the ease with which image analysis tasks may be performed. These considerations are most important if the remote sensing organization will not be in control of system operations.

4.1. Accessibility

The primary factors affecting accessibility are the hours the system is available for use and the time it takes to execute a particular job (turnaround time). Existing applications on a potential host system may limit access by other users to off-peak (evening or weekend) hours. Also, some systems experience periods of very heavy use which may effectively preclude access for image analysis work.

Another factor affecting accessibility is ease of submitting jobs and picking up output. An interactive system enables users to create and submit large batch jobs, and examine their output, from a remote terminal.

4.2. Resource Limitations

Many facilities impose limits on the use of certain computer resources. Examples are the amount of on-line disk space any particular user may have or the amount of memory a job may request during prime hours.

4.3. Operational Support

This category includes both support of day-to-day processing activities and services provided by the computer facility. Daily support considerations include whether the system is always attended by an operator and the willingness of the facility to archive tapes and private disk packs. The availability of custom programming services on a contract basis is desirable if the remote sensing organization does not have its own programming staff.

4.4. Cost

Charges should be determined for program execution and data storage. Program execution costs usually depend on the amount of CPU time and memory used, and possibly on factors such as number of disk accesses made or number of lines printed. For interactive tasks, there is usually an hourly rate for terminal connect time. Some (usually mainframe) facilities also charge for operator services such as tape mounts. Many centers (again, usually mainframe) have different price structures for different ranges of turnaround time (so-called "pay for priority" schemes). Data storage costs include charges for on-line storage on disks or mass storage devices, as well as off-line storage of tapes or private disk packs.

CORSE-81

The 1981 Conference On Remote Sensing Education
May 18-22, 1981 Session No. 5c

"The Earth Resources Laboratory Applications Software (ELAS) in University Research and Education: An Operator Oriented Geobased Information System"*

by

B.L. Coker, T.C. Kind, W.F. Smith, Jr., and N.V. Weber
Mid-America Remote Sensing Center, Murray State University

The ELAS operating subsystem was sponsored and developed by the Earth Resources Laboratory (ERL) of the National Space Technology Laboratories (NSTL) of the National Aeronautics and Space Administration (NASA). The subsystem was designed and written by R.W. Pearson with assistance from B.R. Seyfarth.

The Earth Resources Laboratory Applications Software (ELAS) is a geobased information system. It is designed for analyzing and processing digital data such as that collected by multispectral scanners or digitized from maps.

ELAS is designed for ease of user operation and includes its own FORTRAN operating monitor and an expandable set of application modules which are FORTRAN overlays. On those machines that do not support FORTRAN overlaying, the modules exist as subprograms. Because all of ELAS resides in one FORTRAN program, data inputs and outputs, directives, and module switching are convenient for the user.

ELAS is designed so it can be implemented on most 16-bit or 32-bit machines and is capable of, but not limited to, operating on low-cost minicomputer systems. The Mid-America Remote Sensing Center (MARC) of Murray State University began operating the initial version of ELAS in September, 1980. The version provided MARC was modified by ERL to run on the 16-bit Sperry Univac 77 series mini-computer.

*The bulk of this manuscript has been extracted from NASA report no. 183 (November, 1980) entitled ELAS--Earth Resources Laboratory Applications Software.

The following is a listing of equipment requirements and recommendations to support ELAS:

Mainframe

Floating point hardware
At least 15-bit addressing
Direct memory access channel (DMA)
Program memory

Recommended	100K bytes
Required	56K bytes

Peripherals

Random access disk memory; recommended minimum 67-megabyte
Magnetic tape drive: 800 or 1600 characters per inch (CPI)
User's terminal: 300-baud rate or greater
Image display with applicable hardware

Figure 1 shows the recommended hardware configuration.

Logically, the ELAS software can be divided into two major components: the operating monitor and the application modules. The monitor is written in FORTRAN and uses some machine-dependent routines to accomplish I/O and control functions.

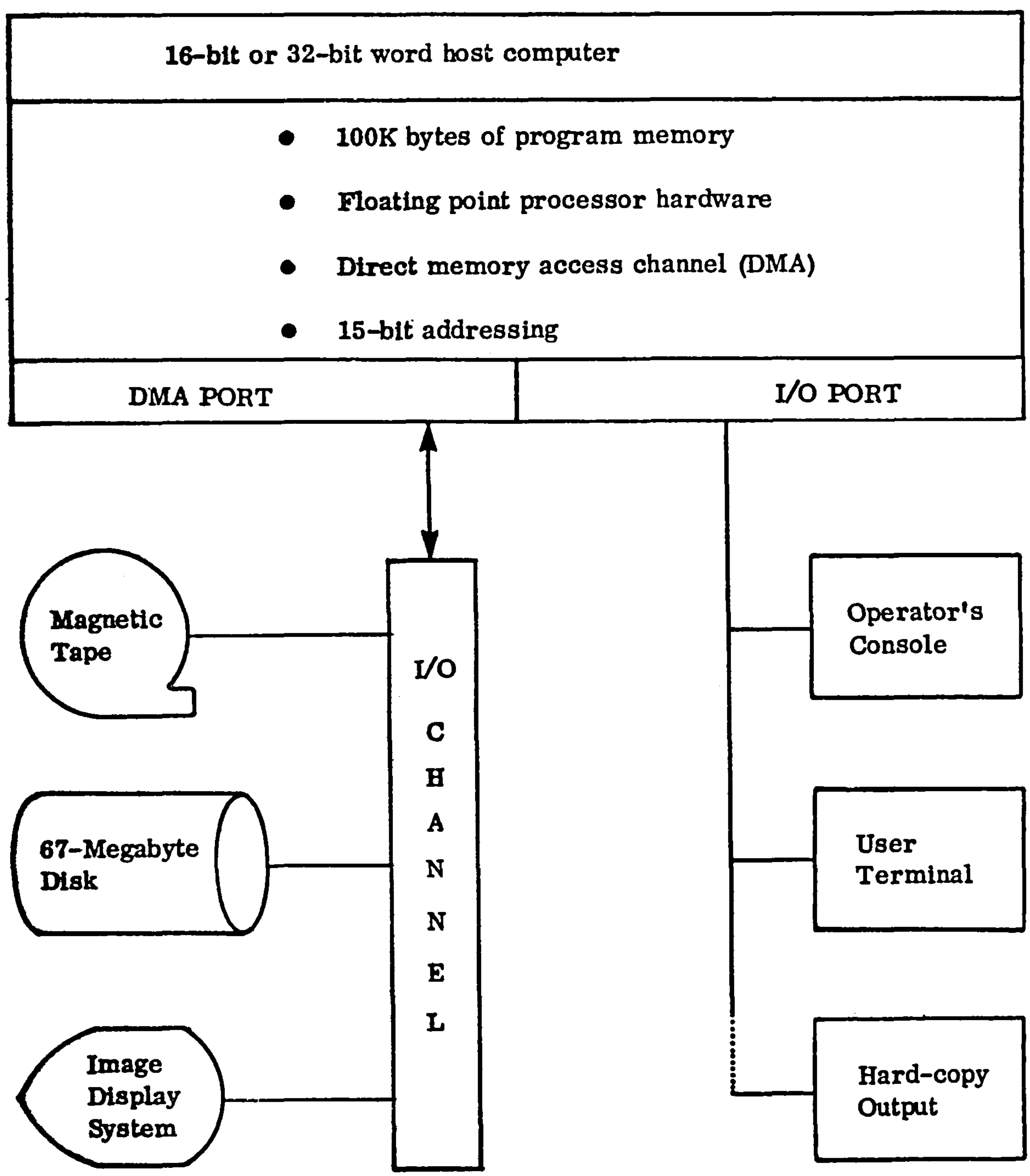
The application modules are also written in FORTRAN, but rely on the operating monitor for machine-dependent functions. The applications exist as common free, calling list free, FORTRAN overlays or subroutines. Needed applications are swapped in and out by the monitor.

The ELAS subsystem requires an interactive image display system. It was developed on an Interdata (Perkin-Elmer) 8/32 computer with a Comtal series 8000 image display system. ELAS can accommodate other brands of image display systems if a software driver is written for that particular image display system/computer combination.

It is anticipated that the users of the ELAS subsystem will be those centers that process remotely sensed scanner data, especially the multispectral data produced by the NASA Landsat satellites. In addition to Landsat multispectral data, the ELAS subsystem will also support the processing of other data such as aircraft scanner data, the return beam vidicon (RBV) data of the Landsat satellites, digitized topographic data such as those distributed by the National Cartographic Information Center (NCIC), and numerous other ancillary data such as soil types and rainfall information that can be digitized.

Most of the centers that use the ELAS subsystem are involved in landcover analysis and data base construction and manipulation. To facilitate this analysis, the ELAS subsystem supports many algorithms. A few examples are given in the following list:

Figure 1 -- Recommended ELAS Hardware Configuration



- Derivation of training statistics
- Classification of data using a maximum likelihood scheme
- Registration of an image to a map
- Numerous display capabilities of the image data
- Manipulations with polygons that define areas within the data
- Production of concatenated data sets
- Implementation on a point-by-point basis of any algorithm that can be determined by a programmable calculator instruction set
- Regression, correlation, and other statistical analysis of the multivariate data sets.

The following is a representative listing of some ELAS operating and application modules:

- NCIC topographic data manipulation
- Plot tape generation
- On line digitizer
- 3-D perspective
- Shoreline length
- Water body classifier
- File manager.

General inquires relative to ELAS may be directed to:

CHIEF
INFORMATION SYSTEMS DEVELOPMENT
AND ANALYSIS GROUP
EARTH RESOURCES LABORATORY
NATIONAL SPACE TECHNOLOGY LABORATORIES
NSTL STATION, MS 39529

Specific questions relative to operating ELAS on Sperry Univac V-77 minicomputers may be directed to:

DIRECTOR
MID-AMERICA REMOTE SENSING CENTER (MARC)
MURRAY STATE UNIVERSITY
MURRAY, KY 42071

Discussion:

The discussion centered around problems in finding or choosing image systems and adapting them to the university system.

The first topic discussed was that of dealing with large jobs. Most of the micro processors cannot handle large jobs, therefore, it is often necessary to have a large computer system available to unload the large jobs onto.

The second topic was different image systems available to match larger computer systems. Some of the names mentioned were: ELAS, the Mini VICAR, Stanford, Data systems, and Interpretation Systems Inc. of Kansas (Lab Electronics of Virginia). It was suggested that interested parties also check into an NSF report on Transportable image processors.

The next topic was concerned with special machines that a company promotes as the latest and best and then drops. It was noted that if the machine has a GSA listing, the company is legally required to support the machine for six years. It was also pointed out that most vendors take steps to insure that software for an older model may be shifted to an updated machine.

Further discussion included comments on display compatibility. Not all display software fits all machines. If you are going to adopt an image system with a display, be sure the display will work on your machine.

The final topic was concerned with the fast moving pace of memory technology. Prices are coming down and there is more K per chip. This is great except when you wish to buy a small amount of memory to maintain an old machine. It is often cheaper to replace all the memory. A vendor suggested that one should attempt to match the learning curve to machine capability. Even so the machine may have to be replaced every five years.

For slightly more detail see "Selection of an Image Analysis Computer System" from Technology Applications Branch, NASA - Ames Research Center, M/S 242-4, Moffett Field, CA 94035.

In addition a three-volume report Computer Software for Spatial Data Handling has been published jointly by the Commission on Geographical Data Sensing and Processing and the United States Geological Survey. The report documents over 700 programs and geographic information systems classified by general subject matter. A special index at the end of Volume 1 cross-classifies the entries by computer type, programming languages, etc. It is possible to obtain a copy of all or part of the inventory in machine-readable form. The inventory represents the only substantial, cross-section examination of existing software in the general spatial data handling area. Contact Dr. D.F. Marble, Geographic Information Systems Laboratory, Department of Geography, State University of New York at Buffalo, Amherst, NY, 14260.

Participants in Discussion on Image Processing
on Small Computer Systems

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Session 5-D

Geographic Information System Considerations For Low-Cost Digital Image Processing

Highlights:

The discussion on geographic information systems was chaired by Floyd Henderson and Michael Dobson, both of the State University of New York at Albany. Recorder for the session was Jim Tilton, Purdue University.

CORSE-81

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Five Contexts for a Geographic Information System[1]

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These remarks about geographic information systems and low cost digital image processing are made with anthropology rather than geography as a background discipline. In my own teaching and research the emphasis is on tropical and near-tropical populations, especially in arid areas of the Third World. Thus a primary concern is with the human origins of changes in the landscapes under analysis. This may make a difference in the expectations of what a geographic information system (GIS) can or should do, both in teaching remote sensing and in research using remote sensing as a tool.

For example, in northern latitudes Landsat data analyses can be checked against many independent spatially oriented information sources such as a variety of maps and calibrated aerial photography. But in southern tier countries such independent data sources are rare, and fieldwork observations and informant statements are important in evaluating the results of Landsat classifications. As an early user of the IMPAC system for microcomputer analysis of Landsat data on the tropics and sub-tropics, I can see five contexts in which a resident GIS program would provide important advantages. These are:

1. time-series analyses of multiple sets of Landsat data for the same area but for different dates and seasons;
2. a multi-stage approach involving the best fit between Landsat data and controlled aerial photography;
3. a capability for re-doing the geometry of approximately oblique aerial photography to approach the vertical point of view of Landsat;

4. aligning the Landsat data with other information sources such as maps and field surveys; and

5. providing pointers to relevant textual data, such as statements by local informants or excerpts from the literature pertaining to the Landsat areas being analysed.

The above expectations are related to the emphasis in anthropology on the importance of perceptions held by local informants--- that is, on-the-ground fieldwork--- as well as what is sometimes called the "holistic point of view." With respect to fieldwork, a resident GIS program must be capable of handling information with and without a strong spatial component. Thus ground observations may include mapped, ecological surveys as well as the demographics of local settlements, also mapped. Since landscape changes through time are very much a concern, the GIS program should be able to handle multiple sets of such data. The present IMPAC system has the capability of handling up to 16 bands, and a resident GIS program seems a real and exciting possibility. At the moment, however, data entry remains problematic, especially for information lacking a clear spatial component.

The holistic point of view requires an additional capability. The point of view suggests that we attempt to discover the nature of a cultural system through the functioning of its parts. It also suggests that any particular part--- a subsistence system such as swidden cultivation, for instance--- is understood best in terms of some other part or parts, perhaps a political or religious system, or both. Whereas the subsistence system is likely to have a strong spatial component, informant statements on politics and religion do not. These non-spatial data sets can be crucial to understanding the events taking place on the ground and affecting both the local and the regional landscapes. Thus a GIS program should have the capability of marking or pointing to these non-spatially oriented information sources as well as those more conventionally associated with Landsat data analysis. One possiblity is to map the distribution of believers in a politico/religious system and then use such a mapping as a masque within which Landsat classifications will be made.[2]

In short, with a GIS program in place, multiple sets of Landsat data and other data sources such as aerial photographs, maps, ground observations, informant statements and textual materials may all lead to the discovery of unexpected interrelationships. Perhaps a GIS program is really a discovery tool. But full understanding is likely to require the use of non-spatial data such as informant statements and documentary or literary materials. Pointers to these kinds of data will enhance the value of a GIS program in anthropology as well perhaps as other disciplines.

NOTES

[1] A National Science Found Scientific Equipment Grant SER 79-14954 made possible the acquisition of the IMPAC system for microprocessor analysis of Landsat data. IMPAC is the trademark of Egbert Scientific Software, P.O. Box 42, Greenport, NY 11944. The opinions expressed here are those of the author alone.

[2] Egbert, Dwight. 1981. Personal communication.

CORSE-81

The 1981 Conference On Remote Sensing Education
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GEOGRAPHIC INFORMATION SYSTEM CONSIDERATIONS FOR LOW-COST DIGITAL IMAGE PROCESSING

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Panel Discussant

The Department of Geography, University of Colorado, Boulder, purchased a low-cost digital analysis system from Egbert Scientific Software, Greenport, N.Y., in 1980. The IMPAC system is capable of creating and displaying full color multi-spectral classification maps. It also has the capability for full statistical analysis, histogram generation, and image ratioing and correction. The hardware for implementing the system, including a Vector MZ microprocessor with dual mini-floppy disk drives, a video terminal, a line printer, and a 300-baud acoustic coupler was purchased on bids from non-local jobbers advertising in national magazines. The remaining hardware, including a control module, a modified Sony color TV, and modified circuit boards for the Vector MZ was purchased from Egbert Scientific Software, along with the IMPAC software. Dwight Egbert, president of the company, came to Colorado to install the system, and train users. Additional costs included site-specific needs (security measures for the room in which the equipment was installed, installation of electrical circuits and a dedicated phone line), and supplies (mini-floppy disks, and line printer paper and ribbons). Finally, five Landsat tapes were purchased from EROS Data Center. These covered the Colorado Front Range Corridor at different times during the year, and portions of the western half of the state.

A major problem with installation and operation of the IMPAC system surfaced quickly. The system must be interfaced with a mainframe computer so that data from the full Landsat scene can be read from the computer compatible tape onto the mini-floppy disks used by the IMPAC system. IMPAC Utility 360 is included with the IMPAC software, written for an IBM 360, and selects a 128 X 128 pixel area for analysis. Colorado's computer is a CDC 6400, and major problems arose in attempts to translate from one mainframe to the other. Problems were compounded by the fact that Egbert Scientific Software's suggested consultant was located in New York. Documentation for the CDC was incomplete, and the program as originally written and rewritten exceeded system capabilities. Communication between local programmers and the New York consultant failed to clear up problems.

As a result, ESS now recommends that potential purchasers of the IMPAC system either obtain access to an IBM 360 mainframe, or else consult with local programmers for translation. In spite of the failure of Colorado to adequately solve programming problems, the IMPAC system worked well with mini-floppy disks produced elsewhere. System costs were quite low compared to systems with comparable capabilities, and the IMPAC system fulfilled its principal mission in the Department of Geography -- to provide instructional facilities for basic digital analysis techniques.

CORSE-81

The 1981 Conference On Remote Sensing Education
May 18-22, 1981 Session No. 5D

DEVELOPMENT AND IMPLEMENTATION OF A LOW COST MICRO COMPUTER SYSTEM FOR LANDSAT ANALYSIS AND GEOGRAPHIC DATA BASE APPLICATIONS *

The use of computerized geographic data bases for representation of spatial variables has undergone generations of development since its early 1970's beginnings with the inception of Harvard's GRID and IMGRID computer programs for multivariate spatial analysis. Geographic data analysis has subsequently been moved from large computers to minicomputers and now finally to microcomputers with radical reductions in costs associated with planning analyses.

After the implementation of NIMGRID (New IMGRID, a raster oriented G.I.S.) on the microcomputer, the authors have implemented analysis programs designed to process Landsat satellite data to be used as one element in a geographic data base. Programs for training field selection, supervised and unsupervised classification and image enhancement were added to the microcomputers' repertoire. Enhancements to the color graphics capabilities of the microsystem were made to allow the simultaneous display of over 32,000 colors plus one graphics plane on an

RGB color monitor. These enhancements allowed display of three channels of Landsat data in a color infrared format on the image display. The simultaneous showing of three Landsat channels greatly increased the capability of the micro system for performing training field selection on a Landsat data set. The capacity of the micro color graphic unit for 16 or more bits (64,000 + colors) in a display generator is normally only found in custom designed color interfaces or expensive image processing systems such as COMTAL, RAMTEK, DeAnza, Grinnell, etc., yet the cost of the micro based system is less than the least expensive of these.

The basic microcomputer hardware needed to perform NIMGRID analyses and most Landsat analyses includes the following:

1. Z-80 base micro computer system
2. Floppy disk drives
3. Printer (character, dot matrix, or graphics)
4. Video console
5. One color display interface and RGB monitor

In the microcomputer version of NIMGRID, the keywords are implemented as chained main programs with interactive prompting for user responses. Operations for indexing, overlaying, matrixing, recording, as well as those for circular searching and clustering are available on the Z-80 micro system. A typical matrix operation on two variables (256 x 240) takes approximately five minutes on the microcomputer as compared to two to three minutes on a minicomputer.

The software for Landsat processing that is available on the micro system includes the following:

1. Training field selection
2. Histogram generation and display
3. Color infrared display and enhancement of Landsat channels
4. Ratioing of two Landsat bands
5. Variable density stretch for each channel
6. Unsupervised clustering algorithms
7. Maximum likelihood classification algorithm
8. Parallepiped classifier for quick look
9. Geometric corrections for mapping Landsat data into a standard map projection (UTM or Lat/Lon)
10. Display of RBV data

These programs and others currently being implemented form a core set of analysis programs to be used with Landsat data. Other programs for image enhancement, feature selection, and multidate analysis will be implemented in future versions of the system.

The significant reduction in cost for micro computer G.I.S. with Landsat capabilities compared with larger computer systems provides an opportunity for an expanded and diverse user community, including small businesses such as Landscape Architecture / Planning / Engineering firms and universities. With new disciplines becoming involved which may not have dealt with data processing in the past, it becomes especially important to facilitate "non-computer type" users by designing software in a conversational and user-friendly structure. In all operational software presently developed as well as that under development on the ERDAS micro system, this was achieved through a series of menu selections and question/response type statements which are literal (in English) and avoid requiring the user to enter operating system commands or other data processing terminology.

It is also important to recognize that different levels of users exist, many of whom may indeed have their own programming capabilities and interests in modifying a given system for special applications.

Therefore it is equally important to provide applications source code for the basic software packages as well as documentation on its theorv and use, with standard FORTRAN being used wherever appropriate.

A second application issue is the scale of implementation of a micro computer G.I.S. capability. The user of such a system should be able to operate in two modes:

1. As a stand-alone system, to be used on an interactive basis
2. As an intelligent terminal to a larger computer for data transfer and selected processing if such resources exist.

Generally, the scale and time frame of a particular project will determine which option should be exercised, or both.

A third application issue is one of training and information dissemination. This area of interest is enhanced particularly well by one major aspect of the micro system: transportability. Rather than require field personnel or interest groups (eg. a public meeting or workshop) to come to a computer center, the micro can be brought to them. This not only has the potential to address public input in a real-time manner on many projects, but also allows a constituency to better understand the method and criteria employed by a project manager. Further, alternative scenarios can be created, displayed, modified, copied, and discussed.

In the future the micro based geographic data base and Landsat processing system will be expanded to include software for:

1. Polygon input data
2. Census data
3. Visual Modeling (3 dimensional perspective)
4. High resolution Landsat D
5. Other related satellite data (weather, etc.)

The final goal is to provide a non-technical user with an easy to use, cost efficient tool for design, planning, analysis and education.

* by Nicholas Faust, Georgia Institute of Technology, and Lawrie Jordon, ERDAS, Atlanta, GA

Additional comments and discussion:

N. Faust - The user of Landsat information and processing systems will not generally be the programmer or someone with a great deal of statistical and computer background. A very "friendly" user system is needed to accommodate these people. ERDAS fulfills this need.

Discussion - Maximum likelihood classification takes about 20 days for a full Landsat frame. A table look-up version of a maximum-likelihood classifier that takes 3 or 4 days is now being perfected.

To get an adequate microprocessor system to do significant remote sensing research one needs to spend around $40-50,000.

Participants in GIS Discussion

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TURNER, Eugene
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Session 6-A

NASA's Role in Remote Sensing Education

Highlights:

This session was organized and chaired by Dr. Nicholas Short of Goddard Space Flight Center and consisted of talks by the manager of NASA's Regional Remote Sensing Applications Program and speakers representing a spectrum of NASA-funded remote sensing technology transfer programs. The final paper dealt with sources of support for remote sensing research and education. Copies of the papers appear on the following pages.

CORSE-81

The 1981 Conference On Remote Sensing Education
May 18-22, 1981 Session No. 6

REMOTE SENSING EDUCATION IN NASA'S TECHNOLOGY TRANSFER PROGRAM

BY: RICHARD H. WEINSTEIN
NASA HEADQUARTERS

INTRODUCTION

Education in remote sensing has been an important component of NASA's Technology Transfer Program. This paper reviews the relevant activities of the Technology Transfer Program over the past five years and presents a perspective on future directions.

TECHNOLOGY TRANSFER PROGRAMS

NASA's Technology Transfer Program was established in 1977 to extend the benefits of NASA developed space technology to a broader sector of the economy. Remote sensing has been a principal focus of activity with major attention to remote sensing education in the Regional Program and the University Applications Program.

Regional Remote Sensing Applications Program

Since 1976, NASA's Regional Remote Sensing Application Program has been directed at making Landsat technology available to state and local government users through a systematic program of liaison, training, technology demonstration and technical assistance. The NASA Ames Research Center, Goddard Space Flight Center and National Space Technology Laboratories operate Regional Centers serving all 50 states (Fig. 1).

The specific objectives of training efforts in the program have been two-fold, namely (1) the short term goal of preparing state/local government technical personnel for direct participation in the technology demonstration projects; and (2) the long term goal of building a self-sustaining base for training of additional resource managers in the state. Although the rather limited exposure of participants in these programs can hardly qualify them as experts in remote sensing, the program does provide a start in building a continuing operational program.

Basic training for state resource managers assumes only discipline expertise and/or computer systems experience - but no familiarity with remote sensing. Training, in groups of 5-15 requires 1-2 weeks, depending on the experience of the participants. Since 1976, detailed training in data analysis has been provided to approximately 1500 in over 40 states, including over a thousand state government officials (Fig. 2).

Broadening the base of in-state expertise to make it self-sustaining has generally involved universities. In some states (e.g., South Carolina, Louisiana, Vermont, Oregon) university involvement is facilitated by their designation as host for the state Landsat data processing system.

University short courses have been used in the Southern Region to establish university programs for training state and local personnel in the operational use of remote sensing. To date short course programs initiated in 11 states in the Southern Region have trained over 350 university faculty in the application of remote sensing.

In the Eastern Region, summer residence programs sponsored in cooperation with the American Society of Engineering Education (ASEE) have provided 26 university professors in 13 states with an opportunity to spend one or more summers at the Goddard Space Flight Center. There, they receive instruction in remote sensing and develop their own remote sensing application projects with the assistance of NASA personnel. A self-instruction course in remote sensing (to be published this year) consists of a 500 page instruction manual with over 300 illustrations, practice exercises and simulations.

In the West, a Remote Sensing Science Council has been comprised of one university representative from each of the 14 states served by the NASA Western Regional Applications Program (WRAP). The Council has inventoried the remote sensing programs available in 48 western schools, served as a forum for exchange of available educational materials and conducted two cooperative training seminars.

Also, conferences such as this have been used as a mechanisms to bring together practicing professionals and educators in the field of remote sensing. A series of three Regional conferences involving all 50 states, was held in the fall of 1978 and is being repeated this year. University educators constituted 25% of the 485 non-NASA attendees in the 1978 conferences and a similar percentage at the two Regional Conferences held to date this year.

Finally, the documentation produced in the course of the Regional Program activities of the past 5 years represents a substantial body of raw and finished material for the expansion of remote sensing education (Fig. 3).

University Applications Program

NASA has worked since 1974 with the academic sector to develop and strengthen related curricula and basic research through the University Applications Program. To provide future resource managers and researchers with the detailed skills to develop and apply Landsat and future satellite technology, remote sensing programs have now been established at universities in 25 states (Fig. 4).

The universities work with state and local governments in applying this technology to current operational problems with demonstrated benefits to the taxpayer. A survey of this program conducted in 1978 showed that they had indeed demonstrated the value of the technology to state and local governments since they added about $1 million in 1977 to these same programs for additional remote sensing products. It is estimated that this number currently exceeds $2 million.

In order to distribute the capabilities developed in these programs nationwide while maintaining a constant level of total program funding, each year one or two programs are phased out and new ones are initiated at universities in other states.

In addition to approximately 3000 students annually enrolled in interdisciplinary remote sensing courses, these centers also provide support for training and experience in remote sensing research and applications to about 400 graduate students each year and research opportunities for about 200 faculty. The University Applications Program is now being extended beyond remote sensing to other disciplines.

User Requirements Program

A pilot study has been undertaken to utilize other educational institutions. NASA established a 12-24 month program with the Environmental Research Institute of Michigan (ERIM) to investigate methods of making Landsat technology readily available to a broader range of local private sector firms through community colleges.

The network used in this effort involves NASA, university research institutes, community colleges, and local private and public organizations. The methodology employed by the program gives local users an opportunity to obtain "hands-on" training in Landsat data analysis techniques by sponsor (ERIM) trained community college staff using a low cost, desk-top terminal.

FUTURE OUTLOOK

At the present time the future of the NASA Technology Transfer Program is undetermined, pending review of the FY 1982 Budget by the Congress. Regardless of the outcome, the extensive committments of state governments, federal agencies and others, planning for an operational system and the accumulated experience of the past several years suggests a larger, more active and, possibly, more independent role for the education community.

A recent report by the National Conference of State Legislatures estimated growth of state investments in Landsat related activities from $13M through 1978 to $28M through 1980. Where four states had Landsat data processing capabilities in 1978, they now exist in approximately 16 states - with others on the way. There is clearly a growing market for remote sensing education.

One measure of technology maturity is the point at which its use - and preparation for its use, i.e., education - becomes end user rather than technology sponsor supported. This has been happening in the University Applications Program for several years and the growth in state government affiliated processing capabilities is expected to accelerate this process. There are also several things the educational community can do to enhance the long term viability of the technology.

First, it's important to recognize that the outside (user) world views remote sensing as a tool, not a discipline. It may be taught as a discipline but the educational community must be prepared to treat it as only a means to an end in dealing with end users to get their support.

Second, operational users are very conservative. They probably don't care where information comes from as long as it is reliable. Trying to "sell" a particular technology (or application) before it's ready can do long term damage to credibility; the degree to which users can/will accept risk must always be considered in dealing with them.

Third, our experience has shown that Landsat data is most useful - perhaps even only useful-when combined with other data. Geographic information systems are becoming more widely available, accepted and utilized. Teaching remote sensing in this context can produce major benefits.

Finally, continued growth in remote sensing education must depend in part on the collective strength of the educational community, i.e. on cooperation. The resources are there - people, curricula, techniques - but there's an urgent need to develop better mechanisms for internal communications, e.g. university networks, professional society sponsorship, etc. The payoff in terms of long term acceptability of remote sensing is clearly worth the price.

REGIONAL REMOTE SENSING APPLICATIONS PROGRAM

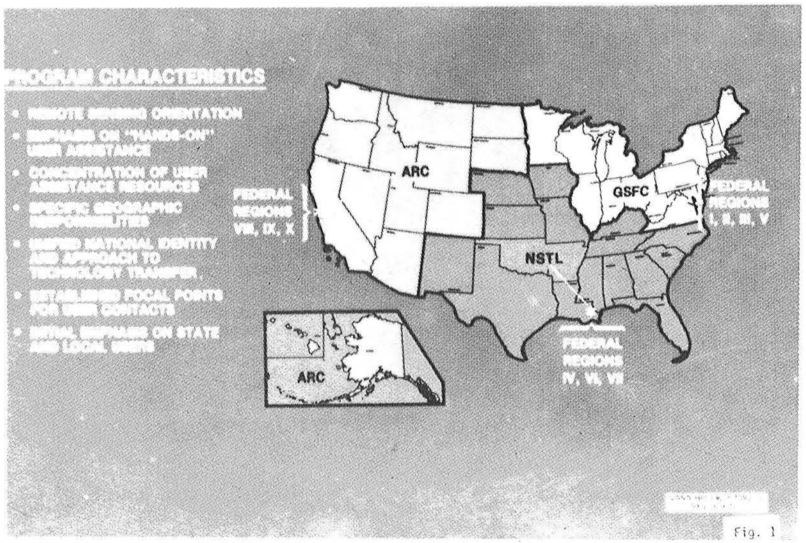

Fig. 1

NASA REGIONAL PROGRAM TRAINING IN LANDSAT DIGITAL DATA ANALYSIS

1976 - 1981 (6 MO.)

EASTERN REGION		SOUTHERN REGION		WESTERN REGION	
DELAWARE	- 9	ALABAMA	- 7	ALASKA	- 57
DISTRICT OF COLUMBIA	- 5	ARKANSAS	- 10	ARIZONA	- 10
ILLINOIS	- 4	FLORIDA	- 35	CALIFORNIA	-275
MAINE	- 8	GEORGIA	- 14	COLORADO	- 45
MASSACHUSETTS	- 1	IOWA	- 11	HAWAII	- 27
MARYLAND	- 49	KANSAS	- 7	IDAHO	- 69
MICHIGAN	- 8	KENTUCKY	- 63	MONTANA	-107
MINNESOTA	- 16	LOUISIANA	- 95	NEVADA	- 2
NEW JERSEY	- 22	MISSISSIPPI	- 86	NORTH DAKOTA	- 37
NEW YORK	- 4	MISSOURI	- 33	OREGON	- 50
OHIO	- 7	NEBRASKA	- 4	SOUTH DAKOTA	- 1
PENNSYLVANIA	- 5	NEW MEXICO	- 27	UTAH	- 0
RHODE ISLAND	- 1	NORTH CAROLINA	- 12	WASHINGTON	- 84
VERMONT	- 17	OKLAHOMA	- 51	WYOMING	- 0
VIRGINIA	- 31	SOUTH CAROLINA	- 14		
WEST VIRGINIA	- 14	TENNESSEE	- 33		
		TEXAS	- 17		
TOTAL	201	TOTAL	519	TOTAL	764

NO TRAINING: CONNECTICUT, INDIANA
NEW HAMPSHIRE, WISCONSIN

NO TRAINING: UTAH, WYOMING

FIG. 2

PUBLISHED NASA TECHNOLOGY TRANSFER DOCUMENTATION

TRAINING PROGRAMS

- EARTH RESOURCES LABORATORY ORIENTATION/TRAINING COURSE IN REMOTE SENSING TECHNOLOGY - NASA NSTL; 11 VOLUMES
- AN INTEGRATED REMOTE SENSING SYSTEM FOR EARTH RESOURCES INVENTORY AND MONITORING - NASA/ARC; 15 MODULES
- ERRSAC REMOTE SENSING TRAINING COURSE - NASA/GSFC; 4 ORIGINAL MODULES PLUS SELECTED MATERIALS FROM LARS, USGS, NSTL AND OTHERS

SPECIAL TRAINING PACKAGES

- LANDSAT TUTORIAL WORKBOOK ON BASICS OF SATELLITE REMOTE SENSING - N.SHORT, NASA/GSFC
- THE WOODSIDE MODULE - NASA/ARC
- ELAS TRAINING MANUAL - NASA/NSTL

SOFTWARE WITH USERS MANUALS

ELAS VICAR/IBIS

ASTEP II OCCULT

TECHNOLOGY SURVEYS

- REMOTE ACCESS COMPUTER TERMINALS FOR IMAGE PROCESSING
- LOW COST COORDINATE DIGITIZERS
- SURVEY OF IMAGE ANALYSIS SOFTWARE

FIG. 3

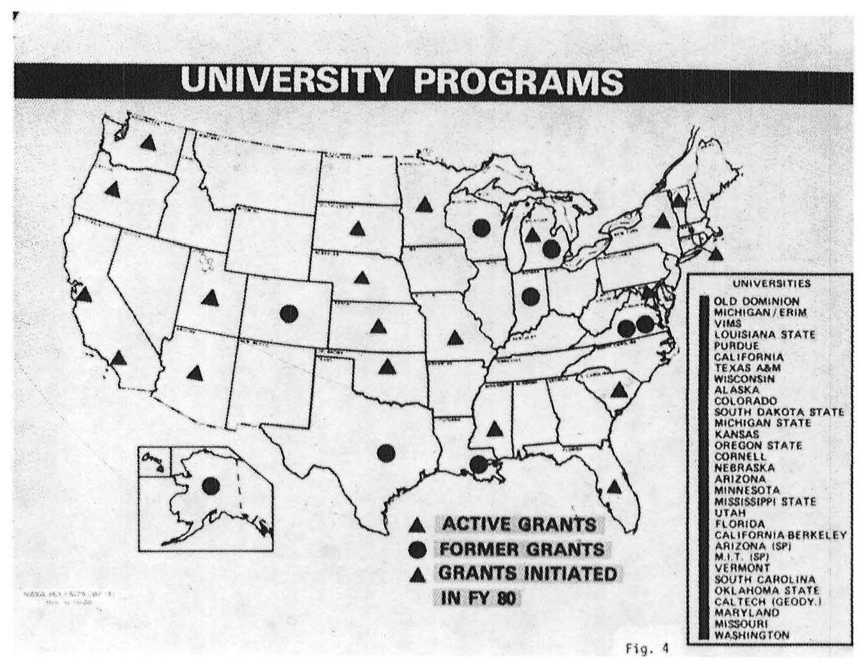

Fig. 4

CORSE-81

The 1981 Conference On Remote Sensing Education
May 18-22, 1981 Session No. 6

Development of the University of Massachusetts Remote Sensing Program: a Grass-Roots Approach

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The University of Massachusetts is extremely grateful and acknowledges the assistance of NASA's Eastern Regional Remote Sensing Applications Center for guidance and training during the early formation of its Remote Sensing Center. Particularly the efforts of their Director of Education, Dr. Nick Short, are applauded.

The topic of this paper is the early stages of development of a remote sensing center at a state land grant university. Several critical strategies were adopted early in the planning process which may be useful to other programs or institutions in similar stages of development.

As the title has suggested, the effort has really been a grass-roots approach. The fact may not be unique, but it is critical. The need for program development was initiated by graduate students recognizing sources of available expertise but a lack of coordination and communication of resources. Colleges and universities rarely initiate programs from the top down, rather they respond best to documented, substantial need within the educational community. Early organizational efforts were to locate the interested students and faculty, to assess present capabilities in terms of staff and equipment resources, and to explore the ways we could develop and expand. NASA's Regional Applications Program personnel gave several excellent presentations at UMass that helped to spark enthusiasm and provide the group with a comprehensive overview of how remote sensing related to the earth resource disciplines.

Actually, UMass has had almost thirty faculty involved in various aspects of remote sensing research for some time. This meant that there was a base of expertise present and although active research can be conducted without programmatic educational emphasis, the reverse is probably not true. If both elements are present they must be well coordinated and can represent a sum greater than either of the parts.

Perhaps the most critical strategic move that was instituted was to strictly avoid trying to develop the program through any one department or college. Initially, an independent research program out of the Provost's office provided very limited administrative support for organizational meetings and a recognized institutional affiliation. However, when the interest and need had been well documented the Graduate School Dean was approached and he formally adopted the program effort. He also appointed an advisory board of deans, faculty, and graduate students who were to guide development efforts and to assist in formulating program policies.

In larger institutions, particularly in public facilities under severe budgetary constraints, inter-departmental and inter-college competition for program budgets and control can become intense. Often pre-existing or long-term strains in relationships preclude effective cooperation and communication for new program developments. Remote sensing is transdisciplinary by its very nature and for program development to be comprehensive the effort must be well coordinated by a neutral but authoritative party such as the graduate dean.

The Graduate Dean formed a Remote Sensing Center and appointed a director. However, the guidelines established by the advisory board ensured that the center was to serve a management and coordination function, not a regulatory one. The distinction must be made explicitly and clearly that the center must not become an "empire" unto itself. The center provides communications within the university, coordinates the usage of "common pool resources" such as the image processing facility, and provides an active development and research grant effort on behalf of and in coordination with individual investigators and departments. The center has no budgetary control.

University administration officials welcomed and supported the effort because it had broad based support, structured coordination, and built upon existing strengths of the staff and facility. The response of the administration has been proven by their budget support to fund further equipment acquisitions such as the image processing facility.

The cooperation of persons at other institutions also can help to make things progress more rapidly. For example, the University of Minnesota, through Doug Meisner, gave us the source code for their computer software system UMIPS. It gave us an opportunity to put an image processing capability on line at a minimal cost. Colleagues of a faculty member at the University of Hawaii gave us TIPS which is a minicomputer-based, highly interactive, floating point image processing software package. Such cooperation between institutions is not only admirable, but also essential for those institutions which are trying to develop programs in remote sensing while facing a total cutoff in funds from government agencies that used to support such program developments. Those institutions which developed under the benefits of government subsidy must recognize an obligation to share those resources which relate strictly to the educational aspects of remote sensing. Cooperation and creative sharing present no real threat to the established remote sensing institutions, rather the educational process, students and research become stimulated and all will prosper. CORSE 81 stands as a testimonial to those concepts.

Conscious efforts to provide service to the public agencies and private business can be a real opportunity and financially rewarding avenue to explore and develop if appropriate. Land grant colleges are obligated in fact to such extension duties for the public good and remote sensing technology transfer can be an excellent way to generate funding, research, and a positive visible image for a program.

Private sector interaction can be lucrative in terms of research, but many institutions have no idea of industrial/commercial needs and how their activities must work to survive and prosper. This area of opportunity is one of the most interesting and challenging and some schools have learned to interact effectively. Professional short courses have become common, are effective educational programs, and are a big business to some schools. It is a market that some predict will soon bottom out as more schools integrate remote sensing programs into their curricula, but as remote sensing technology and applications grow so will the need for advanced professional training. The area of research and development and applications development between educational institutions and the private sector remains to be an area that has been largely unexplored but vital to growth of remote sensing programs. Often teachers and researchers don't listen well, we are used to teaching others how to do things. LISTEN open mindedly and creatively to the needs of the private sector.

Somehow, we need to take advantage of each other's skills more creatively. The remote sensing literature is scattered because of the nature of the topic. CORSE 81 is an important step to maintain good communication between us, but it is unlikely we will be able to convene again for several years unless we can pool collective resources for support, perhaps through a cooperative effort or development of a remote sensing consortium of the professional societies.

The future is entirely uncharted and not without serious potential problems for remote sensing education as we know it now. It is incumbent upon us to be open to change and to be creative in developing alternative ways to accomplish the task.

NASA

CORSE-81

The 1981 Conference On Remote Sensing Education
May 18-22, 1981 Session No. 6

THE UNIVERSITY OF KANSAS APPLIED REMOTE SENSING PROGRAM: AN OPERATIONAL PERSPECTIVE

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INTRODUCTION

The University of Kansas Applied Remote Sensing (KARS) Program has received base funding from the National Aeronautics and Space Administration's (NASA) University Applications Program since 1972 to conduct demonstration projects and applied research on remote sensing techniques which will enable public agencies to better utilize available satellite and airborne remote sensing systems. The KARS Program is a program of the University of Kansas Space Technology Center which is dedicated to the enhancement of research and education in space-related science and technology through multidisciplinary research efforts.

Projects undertaken by the KARS Program with local, regional, state and federal agencies are designed to demonstrate the manner in which remote sensing technology can aid agencies in decision-making policy formulation, planning and in meeting other responsibilities. The KARS Program has provided assistance and services to more than twenty agencies in Kansas. Projects have involved land use/land cover inventory, monitoring land use change, wildlife habitat evaluation, mapping of irrigated lands, surface mined lands inventory, recreational area planning, soil conservation needs assessment, aquatic vegetation mapping, rangeland condition evaluation, noxious weed inventory, urban area analysis, and education and training.

REGIONAL APPLICATIONS PROGRAM

With its strong foundation in applied remote sensing projects the KARS Program began working with the Earth Resources Laboratory (ERL) Regional Applications Program in 1977. As a liaison with Kansas agencies for ERL's Kansas Demonstration Project, the KARS Program coordinated interagency communication, field data collection, hands-on training and follow-on technical assistance for Kansas agencies. The KARS Program also presented results of the Kansas Demonstration Project to several committees of the Kansas Legislature as well as to other interested groups.

As part of the demonstration project ERL delivered to the KARS Program three maps portraying land cover in portions of southwest Kansas. The maps were prepared from computer processed Landsat data in accordance with the information needs of the participating Kansas agencies. Crop types, irrigated lands, rangelands and other cover classes are portrayed on the maps in a variety of colors. One of the maps shows the entire nine county study area at a scale of 1:250,000. The other two maps, at a scale of 1:24,000, depict land cover near Lowe and Holcomb, Kansas in Finney County. After delivery of the maps, KARS staff worked with agency personnel in evaluating the land cover classifications and the utility of the maps for a variety of agency applications.

REMOTE SENSING SHORT COURSE

In cooperation with the ERL Regional Program, the KARS Program has been conducting a series of short courses in Kansas to provide training in state-of-the-art remote sensing technology for University faculty and Kansas agency personnel as well as persons from private industry and federal government. Instructional materials for the courses were developed by the KARS Program to emphasize Landsat digital processing and applications of specific use to the participants.

During the Spring of 1980 and 1981 a series of one-day short courses were held at fifteen locations across Kansas. The course, entitled "Remote Sensing: An Overview," was designed to introduce participants to the fundamentals of remote sensing, and the interpretation and application of information derived through remote sensing techniques. Specific applications of remote sensing were also covered in the areas of agriculture, geology, ecology, geography, land use analysis, range management, recreational planning, regional planning, soil science and water resources. A total of 303 individuals attended the course representing a variety of disciplines from colleges and universities, state, local and regional agencies as well as private industry.

In the Summer and Fall of 1980 two five-day short courses were offered at the University of Kansas Space Technology Center. Two comparable five-day courses will be conducted by the KARS Program again in the Summer of 1981. These intensive five-day courses cover the acquisition, interpretation and application of information derived through remote sensing with specific training and hands-on experience in image interpretation and numerical analysis of Landsat data. The topics covered include:

- Introduction to Remote Sensing
  - Physical Principles of Remote Sensing
  - Remote Sensing Systems and Platforms
  - Landsat
- Manual Image Interpretation
  - Interpretation of Aerial Photography
  - Analysis of Landsat Imagery
- Numerical Analysis of Landsat Data
  - Supervised Classification
  - Unsupervised Classification

Field Data Collection in Support of Remote Sensing
Applications of Remote Sensing
Geographic Data Bases
Acquisition of Remote Sensing Data

Approximately 40 individuals have attended the five-day course to date with another 40 expected in Summer, 1981. Follow-up activities with course participants by the KARS Program have indicated that many participants have developed an understanding of the utility of remote sensing data, and in many instances are attempting to use it on an operational basis through the KARS Program.

CORSE-81

The 1981 Conference On Remote Sensing Education
May 18-22, 1981 Session No. 6

OREGON TRAILS REVISITED

Anthony J. Lewis, Cassandra J. Alexander, Madeline J. Hall,
Dennis L. Isaacson, RJay Murray, Barry J. Schrumpf

Environmental Remote Sensing Applications Laboratory

Oregon State University

Introduction

Although it is somewhat comical to make a comparison of the Environmental Remote Sensing Applications Laboratory's (ERSAL) origin and development with the early trail blazers of Oregon, there are some parallels common to any group embarking on a new adventure. Like the early pioneers, ERSAL experienced many expected, as well as unexpected, hardships. Blazing new trails or cultivating fertile but untilled soil is always fraught with trials and tribulations, but the rewards are also plentiful. The first overland settlers to arrive in Oregon were missionaries. During its early years and with the advent of Landsat 1, ERSAL fit the role of missionaries and sought converts to the new remote sensing technology. The missionaries were followed by farmers who came to establish a new productive and stable life, much as we are now working to institute practical, productive, and cost-effective uses of remote sensing. We've been the trail bosses and guides working with our agency colleagues who are the ones who will make the lasting commitments to this new technological frontier. These pioneer "farmers" are the ones who must take this high technology and make it work day after day for the benefit of Oregon and Oregonians.

ERSAL has been engaged in remote sensing research and the development of remote sensing applications in Oregon since 1972. Funding was provided initially through NASA's University Affairs Program to engage in 1) cooperative remote sensing applications projects with federal, state, county, and local agencies in Oregon concentrating on current problems confronting land resource management and regulatory agencies, and 2) remote sensing technology transfer in the form of formal lectures, workshops, accredited courses or informally through user visits (over 250 annually) to the laboratory facility.

Program

The primary emphasis of the ERSAL research and demonstration program has been the development and application of remote sensing technology in operational resource management programs. Landsat multi-spectral, multi-date digital data and imagery are utilized in concert with high altitude NASA-acquired photography, low altitude ERSAL-acquired photography, and field observations and data. During the past five years ERSAL has been involved in over 30 such projects with various private and governmental agencies (Table 1). Each project has incorporated the "multi" concept (spectral, date, scale, and discipline) critical to the successful completion of any resource management program. Critical to the success of the ERSAL program and the application of remote sensing in Oregon is ERSAL's philosophy of practicality reflected in its determination to 1) fit the available remote sensing technology to the resource problem; 2) directly involve agency personnel throughout the project, and 3) hire staff interested in understanding the user's problem and not in just processing data. The production of customized, inexpensive and useful final products is a hallmark of ERSAL projects. Final products are frequently in the same format that the user is familiar with, e.g. the 1/24,000 orthophotos.

Table 1. Remote Sensing Project Cooperators[1] with ERSAL

1. NASA Ames Research Center
2. U.S. Fish and Wildlife Service
3. U.S. Forest Service
4. U.S. Soil Conservation Service
5. Pacific Northwest Regional Commission
6. Oregon Department of Agriculture
7. Oregon Department of Environmental Quality
8. Oregon Department of Fish and Wildlife
9. Oregon Department of Forestry
10. Oregon Department of Revenue
11. Oregon Department of Water Resources
12. Oregon State Division of Lands
13. Deschutes County Planning Department
14. Morrow County Tax Assessor

[1] In most cases more than one project has been conducted with each cooperator.

Organization and Personnel

ERSAL is organized under the auspices of the Office of the Vice President for Research and Graduate Studies and has six full-time researchers with expertise in a variety of biological, earth, atmospheric and computer sciences as well as image interpretation (black and white, natural color and color infrared photography, radar imagery and Landsat MSS and RBV imagery) and statistical techniques.

Facilities

ERSAL staff have available a variety of equipment and facilities for computer analysis, image interpretation, referencing and reporting.

The laboratory is directly linked to the main frame computers of the Oregon State University Computer Center where ERSAL's PIXSYS (Pictorial Information Extraction System) are installed. This link permits interactive processing of Landsat MSS digital data and utilization of statistical analysis programs maintained by the Center. ERSAL houses a minicomputer with peripherals (tape drive, terminal, electrostatic plotter) for production of low cost paper map products from Landsat classifications. Current equipment acquisitions are adding a digitizing system and color terminal to this cluster of hardware.

ERSAL's image analysis laboratory contains a variety of light tables and film transports for aerial photo viewing and analysis, a zoom transfer scope, and several interpretation stations equipped with scanning stereoscopes and a zoom stereoscope. Portable viewing and interpretation equipment are also available for field use. This laboratory also houses substantial collections of Landsat imagery, U-2 aerial photography and maps of Oregon, and a browse file of Landsat U.S. and non-U.S. coverage on microfilm. From May through September, a collection of weather satellite images coincident with Landsat overpasses is maintained on a real time basis.

Darkroom facilities include equipment for film and print processing, photo enlarging and photo copying. An ozalid machine is utilized for making inexpensive, good quality color composites of Landsat MSS imagery.

A motor driven 35 mm camera with interchangeable lenses and door mount for a light aircraft gives ERSAL the capability to acquire specialized aerial photography at virtually a moments notice.

ERSAL Project Synopses

Columbia Basin 208 Project

Approximately six million acres in five Oregon counties bordering the Columbia River--Wasco, Sherman, Gilliam, Morrow, and Umatilla--were classified according to vegetation cover and land use. A combination of data sources were used including: ground surveys, large and small scale color infrared photography, Landsat 3 RBV imagery, and Landsat 2/3 MSS imagery and digital data. The primary data source was Landsat MSS CCT output used for computer-assisted digital classifications. The study was carried out for the U.S. Forest Service and the Soil Conservation Service as part of a non-point source pollution (208) project.

Blue Mountain Elk Habitat Project

Federal and state resource management agencies have developed forest management guidelines for northeastern Oregon to help provide better protection of big game habitat. Essential to the application of these guidelines is the location and mapping of the various existing habitat units in the Blue Mountains. The Oregon Department of Fish and Wildlife (ODFW), in cooperation with the U.S. Forest Service, has initiated a study to obtain this information. The most efficient method of preparing habitat maps of the area is through the application of remote sensing technology using imagery from aircraft and Landsat.

ERSAL was contracted by ODFW to undertake the image analysis and map assembly work; whereas ODFW personnel collected complete physical and biological descriptions of some 800 site location plots in the study area.

Natural Resource Inventory of Deschutes County

The Deschutes County Planning Department and ERSAL have mapped and compiled statistical summarizations of land cover types in Deschutes County. The county planners, involved in the formulation of a county-wide comprehensive land use plan, will utilize this study to provide the up-to-date resource inventory of the area necessary for rational land use planning. A combination of remotely sensed data was used to delineate the land cover types: 1) Landsat digital data in the forest and range areas; 2) small-scale color infrared U-2 photography and Landsat color composites for agricultural areas, and 3) low-altitude, very large-scale color and color infrared photography for ground information collection and verification. In addition, extensive field work and collateral data gathering was carried out by county planners and ERSAL staff.

Forest Service Landsat Assistance

Field data were collected and image analysis assistance provided to the U.S. Forest Service for the purpose of developing and defining a legend for use in a Landsat-oriented water quality study. The study area included the forested lands of Wasco, Morrow, and Umatilla counties, Oregon. These areas have been inventoried using Landsat digital data since 1978. NASA U-2 high-altitude (1:120,000) color infrared film (CIR) and low-altitude (1:6,000) CIR 9"x9" film flown by the U.S. Forest Service Region 6 Office of State and Private Forestry were used in conjunction with field surveys for the refinement of the Landsat inventory.

Oregon Statewide Landuse Inventory

Since October, 1978, ERSAL has been involved in a 2½ year project inventorying land use throughout Oregon. This work was undertaken for the Oregon Water Resources Department (OWRD) as one step in a procedure to determine present water use and future water needs in the state as an aid in the formulation of future policies by the Oregon Water Policy Review Board.

NASA 1:130,000 color infrared aerial photography was used to delineate land cover types to a 10-acre minimum unit. The land cover types delineated were: irrigated agriculture, non-irrigated agriculture, rangeland, forest land, urban, water, and other. Updating activities were performed via 1:1,000,000 three band (4, 5, and 7) false color composite transparencies from Landsat MSS data.

Western Oregon Timber Clearcut Monitoring Project

ERSAL has been involved in developing an operational system for clearcut monitoring since the passage of an Oregon tax law required the Timber Assessment and Taxation Division of the Department of Revenue to monitor and tax timber on private lands as it is harvested. The technique, as presently used, involves the comparison of multidate Landsat MSS and RBV images and has been found to be reasonably accurate. The increased scale, resolution, and mapping accuracy of Landsat 3 RBV imagery has been helpful in more precisely delineating clearcuts.

Rehabilitation of Burned Forest and Rangeland

The removal of vegetation by wildfires results in increased rates of water runoff and soil erosion. The damage potential by erosion and flooding often requires the immediate initiation of emergency rehabilitation efforts. Success of these efforts in large part depends upon immediate access to information such as, specific resources burned, exact boundary of fire, degree of burn, and critical erosion areas.

During the summer of 1979 cooperative efforts on the part of U.S. Forest Service and ERSAL staff resulted in the application of remote sensing information gathering techniques to the Bridge Creek Fire in the Deschutes National Forest. By the fourth day of the fire, Landsat multispectral data were analyzed to provide pre-fire vegetation maps. Large scale color aerial photographs taken on the seventh day were studied to evaluate areas of high, moderate, and low burn intensities. Information from both data bases was integrated with that from standard procedures for improving estimates of loss, adjusting reseeding contracts, selecting tree species for replanting, and determining use of standing and burned trees.

Oregon Multiple Resource Inventory Project

The primary objective of the Oregon Multiple Resource Inventory Project (OMRIP) is to produce detailed 1/24,000 vegetation cover maps to be used by natural resource managers. These maps will be provided as inexpensive paper copies. Resource information will be computer-stored in digital form for convenience of acreage tabulation and manipulation. The inventory area includes nearly all of Baker, Union, and Wallowa counties in northeast Oregon. In addition to providing map data, ERSAL will consult with and provide training for participants who can identify a specific resource information need to be addressed. Participants will cover costs of specialized products, and provide the supporting data required for their specific applications.

Duration of the project is two years, ending June 30, 1982. The first year will be devoted to identifying participants and resource information applications, acquiring maps and ground and remotely sensed data, detailed planning and conducting workshops. In the second year, the extraction of land cover information and applying this information to a resource management problem will be emphasized.

Update of Fire District Maps

The normal cycle for updating fire district maps is 5 to 7 years; however, there is a substantial need in many districts to have the maps updated more frequently. The State Department of Forestry Mapping Section under the direction of George Shore, and with the assistance of ERSAL, has been evaluating the feasibility of updating fire district maps with Landsat 3 RBV imagery. A pilot study demonstrated that composite maps (½" = 1 mile) consisting of a black and white RBV base and a black line map overlay can be prepared, are useful, and are cost effective. However, several technical problems (availability of Landsat 3 RBV imagery and tone matching) still need to be worked out. The use of multi-color display of RBV and different map separate overlays and the optimum date/season conditions of RBV data are under study as is the production of a Landsat 3 RBV mosaic of the entire state of Oregon matched to the 1/500,000 state map.

TABLE 2. SYNOPSIS OF CURRENT ERSAL PROJECTS

Project Title	Purpose	Cooperating Agency	Study Area	Data Source	Final Product
Columbia Basin 208 Projects	Stratify landscape by cover type.	U.S. Soil Conservation Service, U.S. Forest Service	Five north-central Oregon counties (over 6,000,000 acres)	Landsat MSS digital data; Landsat 2 & 3 MSS imagery; Landsat 3 RBV imagery; large and small scale color infrared aerial photography, and ground surveys.	1/126,720--entire area 1/24,000--over 95% of area (summarized by both county and watershed)
Blue Mountain Elk Habitat Project	Identify, classify (forage, cover, or combination), locate and map existing elk habitat units.	Oregon Department of Fish and Wildlife	Portions of the Blue Mountains (over 500,000 acres)	Landsat MSS digital; high altitude color infrared; low altitude color, and complete physical and biological descriptions of 800 site location plots.	1/24,000 habitat maps (line print copies stored on magnetic tapes)
Natural Resources Inventory of Deschutes County	Map and statistically summarize land cover types.	Deschutes County Planning Department	Deschutes County (1,958,400 acres)	Landsat MSS digital data; high altitude color infrared photography; low altitude color and color infrared, and ground information collection.	1/125,000 and 1/24,000 of entire area
Forest Service Landsat Assistance	Develop a detailed forest and forest-related land cover legend and classify according to the legend.	U.S. Forest Service	Forested lands of Wasco, Morrow, and Umatilla counties (over 1,200,000 acres)	Landsat MSS digital; high and low altitude color infrared photography, and field surveys for refinement of Landsat-derived inventory.	1/24,000 vegetation cover map (summarized by county and selected stream subdrainages)
Oregon Statewide Land Use Inventory (Irrigated Lands Survey)	Delineate and inventory land cover/land use types (seven classes) at a 10-acre minimum for the entire state of Oregon.	Oregon Department of Water Resources	Entire State of Oregon (over 62,000,000 acres)	High altitude color infrared photography; Landsat MSS false color composites for updating land use to base year, and extensive statewide ground surveys over two year period.	land use maps at 1/24,000 and 1/62,500

Western Oregon Timber Clearcut Monitoring Project	Develop an operational system for monitoring clearcuts.	NASA, Oregon Department of Revenue	Portions of Douglas County (480,000 acres)	Landsat 2 & 3 MSS imagery; Landsat 3 RBV; high altitude color infrared, and Oregon Department of Forestry township centered air photos.	1/32,000 township centered air photos
Rehabilitation of Burned Forest and Rangeland	Provide near real time information on pre-fire conditions, specific resources burned, degree of damage and critical areas for rehabilitation.	U.S. Forest Service, NASA	Bridge Creek Fire in Deschutes National Forest (over 4,000 acres)	Landsat MSS digital (prefire vegetation map), and low altitude color and color infrared photography acquired by ERSAL immediately following the fire.	1/24,000 digital maps, 1/10,000 photography
Oregon Multiple Resource Inventory Project (OMRIP)	Provide classified Landsat digital data to users with a variety of resource interests.	U.S. Forest Service, Oregon Department of Fish and Wildlife, NASA, local government agencies	Northeastern Oregon (approx. 10,000,000 acres)	Landsat MSS digital; large-scale natural color, and user-supplied ground data.	1/24,000 interpreted digital classification on magnetic tape for custom product retrieval and manipulation
Agricultural Field Burning	Estimate burned acreage associated with grass seed and small grain crops progressively through the burning season.	Oregon Department of Environmental Quality	Southern Willamette Valley (over 780,000 acres)	Low altitude aerial photography; Landsat MSS imagery and high altitude color infrared photography (systematic and stratified sampling techniques).	Acreage estimation of burned fields in study area with 90% Confidence Interval.

CORSE-81

The 1981 Conference On Remote Sensing Education
May 18-22, 1981 Session No. 6

Sources of Support for Remote Sensing Education

by
John E. Estes
Professor Dept. of Geography
University of California
Santa Barbara, CA

As you know from reading the newspapers, the spring of 1981 is not an ideal one for itemizing potential funding sources for educational programs in remote sensing. In spite of the present lean fiscal outlook, there is a saying that, "The more things change, the more they remain the same." And, as with all sayings which stand the test of time, there is an element of truth in it. From my perspective, the remote sensing funding sources that have been available in the past will, I believe, continue with slight modification to be available in the future. And, while these modifications will have a considerable impact on certain potential funding opportunities (particularly those involving workshop-type activities for state and local users which have been funded through NASA's Regional Programs) the basic pattern of future funding sources should remain nearly the same, with the caveat here that competition will become much stiffer. I will begin this discussion with a brief personal perspective in the form of a historical review. This will be followed with a listing of current funding sources for remote sensing research and end with my feelings on what the future holds.

Past funding for educational programs in remote sensing has come largely in the form of short courses for teachers funded by the National Science Foundation (NSF). In addition, a number of departments around the country were able to purchase remote sensing equipment through NSF instructional equipment grants. Later the National Aeronautics and Space Administration

(NASA) began to fund remote sensing short courses for state and local government and some University participants at a number of institutions around the country through its regional programs. However, viewed in perspective, it is my contention that these programs have had a minimal impact on remote sensing teaching in the United States today. By far the greater impact has come from the funding by a variety of Federal agencies for remote sensing research projects at educations institutions throughout this country.

Probably the best and most significant example of these programs from the University standpoint has been, is currently, and will continue to be Joe Vitale's NASA University Affairs Program. This program, with its long-term step funding of a number of institutions, has probably done more for remote sensing education than any other Federal program in this country today. Why do I say this? As teachers we have all talked and thought about the interactions that occur between teaching and research. If we are really to prepare our students for employment, we must be current in the field. Research funding aids us in staying current. In the past, this funding has allowed us to purchase equipment. We have trained our students to use these tools in classes. Incidently, one of my major sources of concern for the past five-seven years has been the inability of universities to purchase equipment on remote sensing research contracts. I believe this is very short-sighted in this high technology field. How can we train students in the most advanced techniques without advanced equipment? Research funds are also used to publish, and to attend meetings where new ideas in the field are discussed. These ideas travel back into the classroom.

An albeit incomplete listing of Federal agencies who have supported remote sensing research at universities follows:

Army Engineering Topography Lab
Fort Belfore, VA

Army Research Office
P.O. Box 12211
Research Triangle Park, NC 27709

Army Waterways Experimental Station
U.S. Army Engineers Experimental Station
P.O. Box 631
Vicksberg, Mississippi 39180

Division of Electrical, Computer and Systems Engineering
Automation, Bioengineering, and Sensing Systems Program
National Science Foundation
Washington, D.C. 20550 Attn: Norman Caplin, Program Director

Directorate for Science Education
Division of Scientific Personnel Improvement
National Science Foundation
Washington, D.C. 20550

EROS
U.S. Geological Survey
1925 Newton Square East 730
Reston, VA 22090

EROS Data Center
U.S. Geological Survey
10th and Dakota Ave.
Sioux Falls, South Dakota 57198

NASA Ames Research Center
Mail Stop 242-4
Moffett Field, CA 94035

NASA Johnson Space Center
Technical Support Procurement Branch
Houston, TX 77058

NASA National Space Technology Lab
Earth Resources Lab
NSTL Station, MS 39529

NASA Office of University Affairs
400 Maryland Ave S.W.
Washington, D.C. 20546

Office of International Development Cooperation Agency
Pompanio Plaza
1735 No Cynnst
Rosslyn, Virginia

NOAA/NESG Bldg. 33
World Weather M 810
Washington, D.C. 20233

Office of Naval Research
Geography Programs
Code 460
800 North Quincy
Arlington, VA 22217

This list, though not complete, covers a wide range of opportunities. It does not include state, local, and private funding sources. I would hope that if any of you have names to share, someone would begin to compile a master listing. Yet, as you know, we all tend to want to keep some of the best sources to ourselves.

What do I see in the future? I believe we are in for hard times for funding in the short run. However, I also believe the future looks bright in the long run. Despite current fiscal uncertainty and the problems with Landsat D, is there anyone here who really believes we can go back to the days before any earth resources remote sensing capability existed? I don't believe we can go back. The tool, technique, discipline area, whatever you want to call, is too important, too significant in terms of its potential. The technology will be needed and trained personnel will be required. I believe it will be the universities who will train these people. Whether we will accomplish this with benefits associated with research dollars, or from straight courses, or future cirriculum development grants, I cannot say. But my bet would be on the former. And, in all honesty it is my opinion that the funding sources listed above will be the ones which will continue to provide the majority of research dollars in the years to come.

Session 6-b

NOAA's Role in Remote Sensing Education

This session was a continuation of Session 6-a focusing on federal programs that contribute to remote sensing education. Four presentations were made: by Richard Weinstein (NASA Headquarters), Harold Yates (NOAA), Russell Pohl (EROS Data Center), and Daniel Cotter (NOAA). The first two of these presentations are represented on the following pages by summaries prepared by the authors; the final two were summarized for the conference report by Shirley Davis, Purdue University.

Questions raised at the conclusion of each paper are noted briefly.

NASA

CORSE-81

The 1981 Conference On Remote Sensing Education
May 18-22, 1981 Session No. 6

STATUS AND OUTLOOK FOR NASA'S LAND REMOTE SENSING PROGRAM

Richard H. Weinstein
NASA Headquarters
Washington, D.C. 20546

Both Landsat 2 and Landsat 3 are currently in operational status following recovery from technical problems. Landsat 2 is being used for Multi-Spectral Scanner (MSS) data collection; the Landsat 3 MSS is being held as a backup, collecting data only by special request. Data is being collected from the Landsat 3 Return Beam Vidicon (RBV) wherever cloud cover is less than 30%.

The Landsat D program continues NASA's R&D with the dual objectives of assessing the capabilities of the new, Thematic Mapper (TM) sensor and evaluating the requirements for an operational land observing system. The spacecraft will also carry an MSS sensor to provide data continuity for current users and is scheduled for launch in the third quarter of 1982. Landsat D' will be available for launch 12-18 months after Landsat D but will not be launched until Landsat D ceases operation, to provide data continuity through 1988.

Landsat D will have a 3 year design lifetime (vs 1 year for previous Landsats). The measurement capabilities of the TM are expected to be significantly improved over those of the MSS because of more finely tuned and increased spectral bands (7 vs 4 for the MSS) and higher spatial resolution (30 meters vs 80 meters for the MSS). Processing of MSS data from Landsat D will proceed at a normal rate but processing of TM data will be limited to 1 or 2 scenes a day until basic evaluation of the spacecraft sensor and ground data processing system is complete.

Future NASA remote sensing programs will continue to emphasize research, technology development, cooperative projects with end users of data and cooperation with the National Oceanic and Atmospheric Administration (NOAA) on transition to an operational land observing system.

Research will be directed at improving our basic understanding of the remote sensing measurement phenomena and the sensitivity of measurements to atmospheric and surface type and condition variations. This will improve our capability to use remote sensing as a basic measurement tool and to understand physical processes.

Technology development will extend the results of research to practical applications through improved ground data processing and information extraction techniques and development of new sensors such as the solid state multi-spectral linear array (MLA).

Cooperative projects with state/local and other Federal agencies will continue to serve as a mechanism for verifying the ability of technology to meet operational information needs and to stimulate independent use of remote sensing.

Finally, 20 years experinece in the meteorological satellite program provides a model for continued cooperation with NOAA in developing an operational land observing system through continuing R&D and translation of information requirements into technology capabilities.

CORSE-81

The 1981 Conference On Remote Sensing Education
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Harold W. Yates
Director, Office of Research
National Earth Satellite Service, NOAA

The budget that President Reagan presented to the Congress on March 10, 1981, significantly reduced the Federal funds earmarked for the National Oceanic and Atmospheric Administration's (NOAA) implementation of the Operational LANDSAT program. It is true that this will make it more difficult for NOAA to bring this system into being in 1983. It is also true that it adds urgency to the task of moving the system to private sector ownership quickly.

However, it is important to emphasize the positive interpretation of the LANDSAT budget. The Reagan Administration is dedicated to reducing Federal spending and to curtailing Federal involvement in activities that can be handled by the private sector; yet, this budget commits the Federal government to maintaining the continuity of LANDSAT data through 1988. The view of this Administration is that a decade of NASA LANDSAT activities, followed by several years of NOAA management of an operational system, should be sufficient to prove the commercial value of LANDSAT data. Over that length of time, users should be able to determine if LANDSAT is an economically competitive source of data for their purposes. By underwriting the LANDSAT program into the late 1980's, the Administration is giving users time to make their judgements known and the investment community time to implement a commercial system, if it seems reasonable to do so.

This move toward private sector ownership and management was a key point of President Carter's 1979 directive calling for the establishment of an operational system. The current budget does not change the scope of this objective, but it does reduce the time available to achieve it.

NOAA is the Federal agency designated to bring about the operational phase of the LANDSAT program. The resources that this new budget provides for doing this include the LANDSAT D and D' spacecraft, the new LANDSAT Multi-Spectral Scanner (MSS) ground system being developed by NASA at the Goddard Space Flight Center, the MSS product generation system at the Interior Department's EROS Data Center (EDC) at Sioux Falls, and the current level of NOAA resources dedicated to land program management and coordination.

NASA, EDC, and NOAA are working out the details of the cooperative efforts that will be needed to implement the operational system. Current planning calls for NASA to complete the construction of the two D-series spacecraft and the Goddard ground facility. The launch of LANDSAT D is expected in late 1982. Following that launch, NASA will check-out the spacecraft and the new MSS ground system. When NASA and NOAA agree that both the space and the ground systems are performing to specifications, NOAA will assume management and control of the spacecraft and management of the MSS ground system. At the same time, NOAA will become responsible for providing users with real time MSS data and products, as well as MSS and Return-Beam Vidicon (RBV) data and products from the national LANDSAT archive. NOAA and EDC are now developing the management and transfer agreements needed to make it possible to service archive users effectively. These transfers of responsibility to NOAA could take place very early in 1983.

LANDSAT D and D' are projected to have 3-year lifetimes. The present plan calls for D' to be launched after D has failed. If all goes well, these two satellites should provide LANDSAT data continuity through 1988.

While these system activities are going forward, NOAA will continue its effort to achieve private sector ownership and operation of the nation's land observing satellite program. The private sector owner will operate under Federal laws and regulations. NOAA has prepared a legislative proposal to help the Congress, the Administration, and the private sector focus their coming discussions about these matters. At this writing, the legislative package has been approved and forwarded by the Department of Commerce to the Office of Management and Budget (OMB). Under OMB request, other interested Federal agencies are now reviewing this proposed legislation. The OMB will consider the comments from these agencies in its preparation of the formal legislative proposal that will be delivered to the Congress.

While the process of developing the final legislative proposal is in progress, OMB has authorized NOAA to conduct discussions with the private sector relative to the transfer of operation of the land satellite system to that sector. A series of such discussions have already taken place and more are planned. Valuable comments from the private sector are being used to adjust the content of the legislative proposal, as well as to improve NOAA's planning for future contracting and regulatory activities. The private sector has welcomed and supported these early discussions, perceiving that little spare time is available to make this transfer successsful.

The NOAA budget for land activities in Fiscal Year 1982 is currently set at $2.1 million. Of this, $1.4 million is to continue the present level of NOAA management and coordination activities; the remaining $700K is reserved for transfer to EDC to modify the product processing facility there to accommodate MSS data derived from D-series spacecraft. The Federal budget projections for NOAA in FY 1983 will continue the funding of the management activity and add funds for NOAA to operate and maintain the LANDSAT system.

The new budget does not change significantly the resources available to NOAA to manage and operate its environmental satellite systems. However, NOAA, like most Federal agencies, is directed to cut-back on personnel, to reduce spending for equipment and travel, and to reduce its use of consultant services. These across-the-board reductions will have an effect on NOAA's ability to handle other than routine services for environmental users and will delay some of the system improvements that have been anticipated.

This new budget placed an indefinite delay on the joint efforts of NASA, DOD, and NOAA to undertake a National Oceanic Satellite System operational demonstration program.

The current budget does not identify out-year funds for a capital investment to begin operational Thematic Mapper (TM) data services. NASA will be developing the design for a TM ground system during the TM experimental period. As this design takes substance, normal budget request procedures will be followed to obtain the funds needed for this ground system.

It should be emphasized that NOAA is required to work toward the recovery of the operations and maintenance costs of the operational system through sales of system data and products. This implies that prices will be raised above the coming (1981) EDC price increase that is related to inflation. NOAA will be advising users of the specifics of these increases in the next few months. These price increases will also help build the dollar base for attracting private sector investors to the long-range operational system. If LANDSAT data are indeed competitive data, then they should be able to survive competitive pricing in relationship to other data types.

Highlights of presentation by Dr. Russell Pohl, Chief of Data Production, EROS Data Center

Title: <u>The Department of the Interior EROS Data Center Assessment</u>

Status of Landsat
- Timetable of Landsat program
- Cooperation with 150 countries currently

Survey of sales shows that in the early 1970's many geologists bought data; that the 1977 price increase caused a temporary drop in sales. Sale of digital data is increasing tremendously.

User services available include a browse facility and a remote terminal network. EROS is looking for ways to improve delivery time and to provide new products and services. A price increase (the first since January 1974) will go into effect October 1, 1981.

World-wide sources of Landsat data are increasing; U.S. provides 86% of the data bought, Japan and Canada are next.

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Highlights of presentation by Dr. Daniel Cotter, Acting Director of User Affairs Office, NOAA.

Title: <u>The Survey of the Landsat Data User's Needs</u>

NOAA is concerned about problems and expectations of Landsat data users and is looking for ways to move ahead. NOAA is responsible for the operational system starting in 1983 and is now working with NASA and EROS to define the actions and activities needed.

The user survey done by Metrics reflects the diversity of the user community and of the priorities held. A second survey form is being distributed with the request that users will make known their special interests and wishes.

Questions and concerns addressed to speakers:

1. To Harold Yates

Several in the audience expressed concern about the probable increase in cost of Landsat data when data distribution is provided by the private sector and the effect the cost increase will have on casual users and those wishing to experiment with the data. Dr. Yates commented that this was true but that it is hard to say now what the data will cost.

Questions were raised related to SPOT, its data with 10-meter resolution, and US cooperation with France. Dr. Yates indicated that the US will probably cooperate with France relative to SPOT as we have with Landsat. Furthermore it appears that availability of the 10-meter data will be restricted.

When asked if NOAA will be as committed to extending the use of Landsat data as NASA was, Dr. Yates commented that NOAA will do the best they are permitted to do. Additional concerns about the future of remote sensing were expressed by one participant who felt that we now have a program for planned obsolescence with increased costs, lack of thematic mapper data and fewer dollars for research in universities.

2. To Russell Pohl

Do you feel the technology can weather another increase in data prices as it did after the 1977 price increase? Dr. Pohl responded that while there will probably be a drop in the casual users, no one really knows the price elasticity that exists.

Dr. Pohl credited improved delivery time for film data to greater efficiency and fewer equipment problems. He noted, too, an increase in sale of aircraft data.

3. To Daniel Cotter

Will satellite data continue to be available from many sources or will distribution be unified? Dr. Cotter indicated that there is no plan to merge distribution of satellite data.

Dr. Cotter restated the political position that whatever could be moved to the private sector should be.

Session 7 - Panel Session

REMOTE SENSING--THE SHAPE OF THE FUTURE

Members of Panel:

1. Nicholas M. Short (Chairman) - NASA/ERRSAC
2. Richard Hill-Rowley - Michigan State University
3. Roy Welch - University of Georgia
4. David Schwarz - San Jose State University
5. Floyd Sabins - Chevron Research

This panel was convened as a substitution for the originally scheduled NOAA workshops designed to promote dialogue, exchange of views, and other interactions between the university community and federal agency groups involved in development of remote sensing technology. As such, the panel was still able to accomplish this objective in that the community's views were openly discussed in the presence of representatives from NOAA, NASA, and DOI's EROS Data Center leading to occasional cross-discussions between the two groups. The panel program was organized around the 12 topical questions listed in the table on the next two pages. The format generally followed that of consideration of one or two questions at a time by the panelists after which comments from the audience were forthcoming. Highlights of the responses to many of these questions are summarized below.

The first two questions generated nearly 40 minutes of active participation. The panelists made these points:

REMOTE SENSING: THE SHAPE OF THE FUTURE
PANEL QUESTIONS

1. WHAT ARE THE GREATEST NEEDS IN THE UNIVERSITY COMMUNITY OVER THE NEXT 5-10 YEARS FOR EFFECTIVE DEVELOPMENT OF REMOTE SENSING ACTIVITIES ON CAMPUS?

2. HOW DO THE UNIVERSITIES PERCEIVE THE FEDERAL GOVERNMENT'S ROLE IN ASSISTING THEM IN THE DEVELOPMENT?

3. HOW CAN THE UNIVERSITIES SET UP AND SUPPORT EFFECTIVE CONTINUING EDUCATION OPPORTUNITIES TO TRAIN NON-UNIVERSITY USERS? WHAT ARE SOME OF THE PROBLEMS IN DOING THIS?

4. WHAT APPROACHES BESIDES REMOTE SENSING CENTERS SUPPORT SHOULD NASA/NOAA CONSIDER IN ASSISTING UNIVERSITIES TO ESTABLISH REMOTE SENSING PROGRAMS ON CAMPUS?

5. THE UNIVERSITY COMMUNITY IN THE 14 WESTERN STATES (WRAP REGION) HAD A VOICE IN NASA'S RAP THROUGH ITS REMOTE SENSING SCIENCE COMMITTEE (J. ESTES, CHMN.). IS THERE A REAL NEED IN THE FUTURE FOR A COMPARABLE RSSC NATIONWIDE TO ASSIST NASA/NOAA? WHAT SHOULD BE THEIR OBJECTIVES, RESPONSIBILITIES, FUNCTION, LIMITATIONS? CAN SUCH A COMMITTEE OPERATE WITHOUT NASA/NOAA SUPPORT?

6. WHAT WOULD BE THE VALUE OR ADVANTAGES OF EXPANDING THE WRAP DIRECTORY OF UNIVERSITY REMOTE SENSING PROGRAMS TO A NATIONAL LEVEL?

7. EXAMINE THE VUGRAPH NOW ON THE SCREEN. COMMENT ON ANY OF THE ITEMS IN EITHER OF THE COLUMNS.

8. CONSIDER THE RELATIVE ROLES OF THE UNIVERSITIES AND PRIVATE INDUSTRY IN APPLIED RESEARCH APPLICATIONS PER SE, OTHER ACTIVITES WITHIN THE MARKET PLACE. SHOULD THERE BE COMPETITION OR COOPERATION BETWEEN TWO GROUPS?

9. WHAT TYPES OF ADVANCED TRAINING TOPICS WOULD BE ESPECIALLY USEFUL TO UNIVERSITY FACULTY IF OFFERED BY NASA/NOAA/DOI, OTHERS?

10. ASSUME FEDERAL ASSISTANCE TO UNIVERSITIES IN REMOTE SENSING WILL BE LOW IN THE NEXT X YEARS. WHAT CAN THE UNIVERSITIES DO ON THEIR OWN, WITH LIMITED OR NO ASSISTANCE?

11. (NOAA) HOW CAN WE IDENTIFY AND DESIGNATE THOSE GROUPS OF UNIVERSITY AND RESEARCH INSTITUTIONS THAT WOULD BEST BENEFIT FROM--AND CONTRIBUTE TO--REMOTE SENSING TRAINING AND RESEARCH OPPORTUNITIES THAT MIGHT BE SPONSORED WITHIN LIMITED FUNDING CONSTRAINTS, BY THE RESPONSIBLE FEDERAL AGENCIES?

12. (NOAA) CAN THE UNIVERSITY AND RESEARCH COMMUNITIES DETERMINE OR ESTIMATE THEIR ANTICIPATED NEEDS FOR ARCHIVAL DATA, IN TERMS OF VOLUME AND/OR DOLLAR LEVEL OF PURCHASE? WHAT IS THE <u>MINIMUM</u> ARCHIVE LEVEL REQUIRED TO SATISFY BASIC NEEDS OF THE UNIVERSITY/RESEARCH COMMUNITIES? DEFINITION OF THIS LEVEL MUST BE AGREED TO BY JULY 1983 TO ALLOW RESPONSIBLE FEDERAL AGENCIES TO BE APPROVED AND FUNDED TO MAINTAIN THIS BASIC SET.

1. Welch

   - Greatest need is for better data availability
   - Good teaching programs by competent faculty
   - Improved knowledge of ways to process data
   - Low cost digital image processing equipment
   - Better understanding of equipment and software
   - Funding for well-monitored research projects

2. Hill-Rowley

   - Data at prices universities can afford
   - Increased (and easier) access to information
   - Emphasis on visual approach to information extraction
   - More extension course type activities
   - Increase public's prospective of remote sensing

3. Schwartz

   - Less emphasis on "exotic" types of remote sensing
   - Recommitment to CORSE-78 recommendations
   - Help for smaller schools in getting into remote sensing
   - Assistance in keeping up with state-of-the-arts

The audience reiterated some of these statements and initiated some new ideas, including: inexpensive sets of imagery from various satellites; reduced cost software for the universities; simulation of computer methods and products for those without functioning systems; software for microcomputers; ways for smaller schools to access (time-shared) computer networks; more in-depth training programs at federal facilities. While this first question provoked much thought, Joe Ulliman of the University of Idaho restored the participants to reality with a sharp quote concerning a similar session during CORSE-78 at Stanford. "After all is said and done . . . more is said then done."

Some useful comments on the federal role in remote sensing education (question 2) were:

- o Help for some equipment and short courses, and appropriate research projects at reasonable funding levels (direct costs only; universities should forego indirect costs whenever possible)
- o Limited support provided universities show willingness to help each other more rather than rely heavily on "feds"
- o Grants for small computer systems
- o Aid in running "familiarity" workshops both on and off campus--to reach wider professional audiences and thus create more demand
- o Involvement by agencies with vested interests but not now giving support; e.g., Cooperative Extension Service

Education (training) for users not within the normal student body (question 3) was recognized as a legitimate activity for the universities and one to which they can effectively contribute. Several approaches to such training were reviewed. Both short courses and extended low cost continuing education programs were advocated. The high lump sum costs of 1-week courses were cited as an impediment to participation by many state agency people. Deans must be willing to "risk" some faculty and facilities in underwriting off-campus courses that can be sold at "regular" enrollment fees. The training and other university-directed activities must identify the needs of each category of user and thereby tailor courses, etc. to these specific information requirements. The training should be of broad scope and adaptability--emphasis on Landsat rules out many potential users of this time. R. Weinstein of NASA Headquarters reminded the audience at this stage that the Regional Applications Program had in the last 5 years or so provided training (up to a week or more) to about 1500 people and given 1-day orientations or similar briefings to 2500, both at the NASA Centers and on the road.

The question (5) concerned with a possible ad hoc university advisory committee to NASA/NOAA failed to find enough enthusiasm from the university community to encourage action at this time. Also, insufficient interest was aroused in the proposal to develop, perhaps through federal assistance, a Directory of University Remote Sensing Programs similar to that now published under WRAP auspices. Action on that was deferred with the understanding that an organization like ASP might wish to undertake such an effort or to build a directory from the updated surveys on remote sensing education reported by R. Dahlberg at CORSE-81.

The two questions (11 and 12) put forth by NOAA on data needs and data archiving did not elicit any definitive response. One individual reminded the audience that the COSMIC facility at the University of Georgia has functioned effectively to distribute data processing software; a university-based facility dedicated to archiving might therefore serve well as a clearinghouse for satellite earth resources data in the future. Some skepticism was voiced concerning the willingness of the private sector to step in to perform these tasks without at least partial underwriting by the government.

The panel session closed with reactions to two spontaneous questions posed by the chairman. One concerned ways to "educate" the general public on the applications and benefits of remote sensing to mankind. An effective "sales job" could regenerate a ground swell of taxpayer support for the Landsat and other satellite earth observations programs. Some innovative suggestions were produced such as:

- Using Landsat imagery of a metropolitan region as a backdrop for the TV weather reports
- More TV and newspaper ads like those of Chevron, Exxon, and Conoco, that indicate how satellite imagery is used in energy exploration
- A TV special (perhaps in the NOVA series) dedicated to earth observations
- Increased numbers of displays at meetings and other public gatherings
- Expanded use of Landsat in the grade and high schools
- "Plugs" about Landsat on college campus radio stations

The second unannounced question dealt with appropriate follow-ons to CORSE-81. The idea of another such conference by 1982 was positively received. It could be sponsored by ASP or a similar organizations. The alternative of having half-day sessions in remote sensing education at annual meetings was judged insufficient to meet faculty needs--especially those at the smaller universities where opportunities for the training workshops so well received at CORSE-81 might be limited by scarcity of travel funds, etc. Continuing support and encouragement by involved federal agencies may still be necessary. The overall outlook for increasing growth of remote sensing and concomitant educational requirements, was rated as very good despite the current slow-down of federally funded programs. This view was sustained by the recognition that remote sensing is evolving from a "new tool" stage to that of a broad, versatile, and important discipline in itself.

Tutorial Workshops

One of the most popular aspects of CORSE-81 was the series of tutorial workshops given in conjunction with the conference. These two- and three-hour sessions were designed to serve a two-fold purpose: first, they gave participants the opportunity to deepen their own understanding of fundamental aspects of remote sensing, and second, they gave experienced teachers an opportunity to observe the teaching strategies adopted by other educators.

Nine workshops were presented, with five of the nine offered twice and one offered three times. Workshop titles and presenters were:

1. Basic Principles of Satellite Remote Sensing by Dr. Nicholas Short, NASA/Goddard

2. Digital Image Processing Techniques by Dr. Philip Swain, Purdue University, and Ronald Boyd, Computer Sciences Corporation

3. Energy Sources, Spectral Reflection Properties, Atmospheric Effects, and Sensors by Dr. Thomas Lillesand, University of Minnesota and Dr. Ralph Kiefer, University of Wisconsin

4. GIS Analysis: An Academic Approach and Experience by William Campbell, NASA/Goddard; Joseph Berry, Yale University; and Richard Hyde, Butler University

5. Acquisition and Use of 35mm Aerial Photography in Instruction and Research by Dr. Merle Meyer, University of Minnesota

6. Laboratory-Manual Approach to Remote Sensing Instruction by Dr. Floyd Sabins, University of California, Los Angeles

7. Non-Landsat Remote Sensing from Space by Dr. Nicholas Short, NASA/Goddard

8. Introduction to Photogrammetry by Dr. Edward Mikhail and Joe Thurgood, Purdue University

9. Remote Sensing Field Research by Dr. Marvin Bauer, Barrett Robinson, and Larry Biehl, Purdue University

WORKSHOPS 1a AND 1b

BASIC PRINCIPLES OF SATELLITE REMOTE SENSING

This workshop, presented by Dr. Nicholas M. Short of NASA Goddard's ERRSAC, was an extension of the presentation normally given during the 1-day Remote Sensing Orientation Workshop held once each month at ERRSAC's facility at Greenbelt, MD. The presentation is based on the following sequence of general topics, covered mainly through commentaries on approximately 100 35 mm slides (most in the public domain):

1. Nature and Definition of Remote Sensing
2. Historical Development of Remote Sensing
3. Fundamentals of Electromagnetic Radiation
4. Concepts of Spectral Response Curves
5. Infrared and Vegetation Detection
6. Multispectral Remote Sensing
7. The Landsat System
8. Advantages and Shortcomings of Landsat Data
9. Enlargements and Mosaics of Landsat Imagery
10. The RBV Imaging System
11. Value of Digital Processing of Remote Sensing Data
12. Landsat-D
13. Heat Capacity Mapping Mission
14. Seasat Radar Imagery
15. Some Typical Landsat Applications
16. Integration of Landsat Data with Other Types of Data

Notes for the workshop were taken from Activity 1, Some Fundamental Concepts in Remote Sensing, of the Landsat Tutorial Workbook (in press).

Workshop 2

CORSE 81 Workshop on

Digital Image Processing Techniques

by

Philip H. Swain
Purdue University

and

Ronald K. Boyd
Computer Sciences Corporation

I. Principles of Image Processing (Boyd)
   A. What is a Digital Image?
   B. Preprocessing
      1. Reformatting
      2. Subset Extraction
   C. Restoration
      1. Radiometric
      2. Geometric
   D. Enhancement
      1. Intensity Stretch
      2. Ratioing
      3. Color Composites
   E. Pattern Recognition
      1. Concept

II. Pattern Recognition and Decision Theory: An Introduction (Swain)
   A. Applicability of Pattern Recognition in Remote Sensing
   B. Terminology of Pattern Recognition
   C. An Example: "Funny Dice" Game
   D. Classification in the Face of Uncertainty

III. Typical Steps in Numerical Analysis of Remote Sensing Data (Swain)
   A. Introduction
      1. Analysis Flow Chart
      2. Contents of Multispectral Scanner Tape
   B. Statement of Analysis Objectives
   C. Examination of Data Quality
   D. Delineation of Areas to be Analyzed
   E. Selection of Training Samples
      1. Matching distinguishable classes and information classes
      2. Revision of analysis objectives if necessary
   F. Classification and Display of Results
   G. Evaluation and Refinement of Analysis
   H. Preparation of Results for Consumer

IV. Supervised versus Unsupervised Analysis (Swain)

Materials

1. Principles of Image Processing
   (overhead projections by Boyd)

2. The Role of Pattern Recognition in Remote Sensing
   (videotape with viewing notes) by P.H. Swain

3. Typical Steps in Numerical Analysis
   (slide/tape minicourse with study guide) by J.C. Lindenlaub

CORSE-81 WORKSHOP 3

ON

Energy Sources, Spectral Reflection Properties, Atmospheric Effects, and Sensors

by

Thomas M. Lillesand
University of Minnesota

and

Ralph W. Kiefer
University of Wisconsin

Workshop Outline

1. Energy Sources and Radiation Principles
2. Energy Interactions in the Atmosphere
3. Energy Interactions with Earth Surface Features
4. Data Acquisition/Analysis Flow
5. Reference Data
6. Ideal Remote Sensing System
7. Characteristics of Real Remote Sensing Systems
8. Color and Color IR Interpretation Principles
9. Filters
10. Multiple Examples of Color and Color IR Image Interpretation

NOTE: Topics covered paralleled those included in Chapters I and II of REMOTE SENSING AND IMAGE INTERPRETATION, by Lillesand and Kiefer, Wiley, New York, 1979, 612 p.

CORSE -81 Geographic Information System Workshop - Workshop 4

GIS Analysis: An Academic Approach and Experience

<u>Introduction</u> - William J. Campbell
NASA - Goddard Space Flight Center

This 3 hours workshop is comprised of three parts:

- o System Design and Capabilities
- o Academic Course Structure and Experiences
- o Data Base Design and Development

PART I:

A cursory examination of design and concepts embodied in the term Geographic Information Systems. The learning objectives will be:

- o Be able to distinguish between a GIS and a Data Base Management System
- o Have an understanding of spatial data handling by conventional methods versus the automated approach
- o Be aware of GIS design and capabilities
- o Understand the concepts and problem of data base development and management
- o Recognize how a computerized GIS can model conditions in the present "real world" to project conditions in the future
- o Recognize the utility of integrating Landsat and other remotely sensed data into the GIS

PART II:

<u>GIS: An Academic Approach</u> - Joseph Berry
Forestry & Environmental Studies
Yale University

Describes recent development of a graduate level course in geographic informaton analysi at the Yale School of Forestry and Environmental Studies. Part II also describes the fundamental analytic theory coordinated with extensive excersises to demonstrate the practical application of a GIS.

PART III:

<u>GIS Data Base Design and Development: A Practical View</u> -

Richard Hyde
Holcomb Research Institute
Bulter University

An in depth consideration of the problems and pitfalls of data base development as well as a review of a synthetically created spectral data base and an operational multilayer data base and its applications. The purpose of the spectral data base is to make definitive statements on the spatial resolution level requirements or the optimum pixel size for several of the high volume Landsat data user disciplines.

Workshop 5

CORSE-81 WORKSHOP

ON

Acquisition and Use of 35mm Aerial Photography in Instruction and Research

by

Merle P. Meyer
University of Minnesota

Workshop Outline

INTRODUCTION

A. System overview
B. Importance of local PRACTICAL expertise and experience.
C. System capabilities -- and limitations.

FILMS, FILTERS/TIMES OF PHOTOGRAPHY

A. Films
   - Color
   - Color infrared
B. Filters
   - Haze
   - Other
C. Times of photography
   - During the day
   - During the year

AIRCRAFT & PILOTS TARGET STAGE

A. Desirable and undesirable aircraft characteristics
B. Attributes of a good photo pilot

CAMERA SYSTEM

A. Types and characteristics
   - Motor drive
   - Auto wind
   - Shutters
   - Lenses
   - Filters
B. Assembly
C. Operation
D. Storage
E. Troubleshooting

CAMERA MOUNT

A. Basic components
B. Adjustment
C. Care in handling
D. Where to obtain

Workshop Outline - continued

FLIGHT OPERATIONS
- A. Film
- B. Boresighting
- C. Film organization
- D. Flight plan maps
- E. Flight log setup
- F. Equipment checklist

AERIAL PHOTOGRAPHY
- A. Pre-flight
- B. Enroute
- C. On target
- D. Going home

FILM PROCESSING, SLIDE PREPARATION AND STORAGE
- A. Film processing
- B. Slide preparation
- C. Storage

IMAGE INTERPRETATION AND MAPPING
- A. Procurement and use of prints
- B. Image projection and viewing
  - Rear projection
  - Front projection
- C. Stereoscopic viewing
- D. Image analysis and mapping
  - Scale
  - Distance
  - Area
- E. Maintenance and storage

FIELD CHECKING
- A. Slide preparation
- B. Field Viewer use

TECHNIQUES AND APPLICATIONS
- A. Illustrated slide presentation
- B. Mapping change
  - Baseline
  - Future comparisons
- C. Quantitative vs. qualitative evaluations
- D. Typical applications
- E. Discussion of individual problems or application plans

FLIGHT TRAINING
- A. Film preparation
- B. Flight Plan
- C. Equipment preparation
- D. Flight log preparation
- E. Aircraft setup
- F. Practice on photography procedures
- G. Takeoff
- H. Target location, lineup
- I. Overflight
- J. Return
- K. Crew change

Workshop 6a, 6b, and 6c

Laboratory-Manual Approach to Remote Sensing Instruction

by

Floyd F. Sabins, Jr.
Department of Earth and Space Science
University of California, Los Angeles

<u>Introduction</u> - Review of importance of hands-on image interpretation as part of training of students.

<u>Demonstrations</u> - Use of laboratory-manual materials for teaching the following key aspects of remote sensing.

- Testing students' ability to see stereoscopically
- Resolution capability of the human eye and the impact of contrast ratio on that capability
- Basic physical and mathematical concepts that underlie each imaging system, e.g., aerial photography, Landsat
- Basic image structure and format of various data types
- Application of different types of images to various disciplines, including land use, environment, geology, and resources
- Newly deployed imaging systems; e.g., RBV on Landsat 3, Seasat radar, Heat Capacity Mapping mission
- Computer-aided digital image processing

<u>Materials</u>

"Remote Sensing Laboratory Manual" by Floyd F. Sabins, Jr., 1981. Distributed by Remote Sensing Enterprises, P.O. Box 2893, LaHabra, California 90631.

Related materials include the "Instructor Guide" with completed projects and calculations and a set of 35mm slides of completed projects and related material, available as above.

WORKSHOPS 7a AND 7b

NON-LANDSAT REMOTE SENSING FROM SPACE

The workshop, given by Dr. Nicholas M. Short of NASA Goddard's ERRSAC, dealt chiefly with the principles underlying data acquisition and interpretation in the thermal IR (8-14 μm) and the microwave regions of the spectrum. Results from two satellite programs, the Heat Capacity Mapping Mission (HCMM), managed by NASA Goddard, and the Synthetic Aperture Radar flown on Seasat and managed by the Jet Propulsion Laboratory, were also major topics covered in the workshop. The differences in data obtained by active and passive microwave systems were briefly reviewed.

Notes for the workshop were comprised of copies of Activity 9, Other Remote Sensing Systems: Retrospect and Outlook, from the Landsat Tutorial Workbook (in press), which includes details not only on HCMM and Seasat but also treats the meteorological satellites, the Coastal Zone Color Scanner on Nimbus 7, and such future satellites as Landsat-D the the French SPOT.

Workshop 8

CORSE - 81

Workshop on
Introduction to Photogrammetry

The two-hour workshop was divided into two segments. The first was a lecture with an abundance of visual aids, while the second segment consisted of demonstration on several photogrammetric instruments.

The lecture began with the definition of photogrammetry in relation to photo interpretation and remote sensing. This was followed by a brief description of the different sensing systems and photogrammetric applications and products. Emphasis was placed on the basic concepts and the distinguishing features of the discipline. In particular, the requirements for high precision measurements were pointed out in order to obtain quality metric information. Thus, after covering the basic geometry, scale, relief displacement, and parallax, distinction was made between approximate methods and rigorous photogrammetric restitution using analog as well as analytical systems. Examples of a wide range of applications, from industrial and engineering metrolog problems to topographic mapping and space, concluded the lecture.

Photogrammetric instrument demonstration included three different types of equipment: a direct projection plotter (Klesh), an optical mechanical high precision plotter (Wild A-7), and a single-plate image coordinate measuring comparator (Mann Type 422). Photographic imagery was set up on each, and after brief explanation, the participants were given the opportunity to view and manipulate the equipment.

Workshop 9

Remote Sensing Field Research Workshop

M. E. Bauer, B. F. Robinson and L. L. Biehl

Purdue University

Overview of Field Research

- Role of field research
- Experiment design
- Example experiments and results

Radiation and Instrumentation for Field Research

- Radiance, reflectance
- Geometric considerations
- Atmospheric effects
- Instrumentation principals
- Detectors
- Calibration
- Comparison of instrument characteristics

Spectral Information Systems

- Agronomic-spectral data flow
- Field research data bases
- Data access and analysis software

Field Trip to Purdue Agronomy Farm

- Agronomy experiments
- Multiband radiometer and data logger
- Spectral measurement procedures

3 hours

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Numerous other organizations provided informative fliers and brochures as well as exhibit copies of materials. Included in this group were NASA/ERRSAC; NASA/Lewis Research Center; NOAA; USGS, including NCIC; EROS Data Center; Technology Applications Center, Albuquerque; Murry State University's Mid-America Remote Sensing Center; University of Georgia and Georgia Institute of Technology; West Chester State College; University of British Columbia; Earth Satellite Corporation; General Electric; Focal Point Audiovisual Ltd, Portsmouth; Taylor & Francis Ltd, London.

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16. Abstract

The Proceedings summarizes the program of the Conference on Remote Sensing Education (CORSE-81) held from May 18-22, 1981 at the Purdue University in West Lafayette, Indiana, included is the schedule of activities, lists of participants and exhibitors, preprints of most of the papers given during the seven sessions, and a review of content presented at the nine workshops.

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